The Engineer

SEPTEMBER 28, 1956 28 ESSEX ST., STRAND, LONDON, W.C.2. TWO SHILLINGS

UNIVERSITY OF MICHIGAN

ENGINEERING LIBRARY

Widening the choice of resilient jointing materials

LANGITE

Langite — which for more than thirty years has been used so extensively wherever there is an oil joint to be kept tight — utilizes the natural resilience of cork, bonded together by an original process.

NEOLANGITE

like Langite, embodies cork, but in this case is bonded with appropriate synthetic rubbers.
NeoLangite is used extensively on transformers, aircraft, motor vehicles, etc.; it has a considerable mechanical strength and recovery after compression.

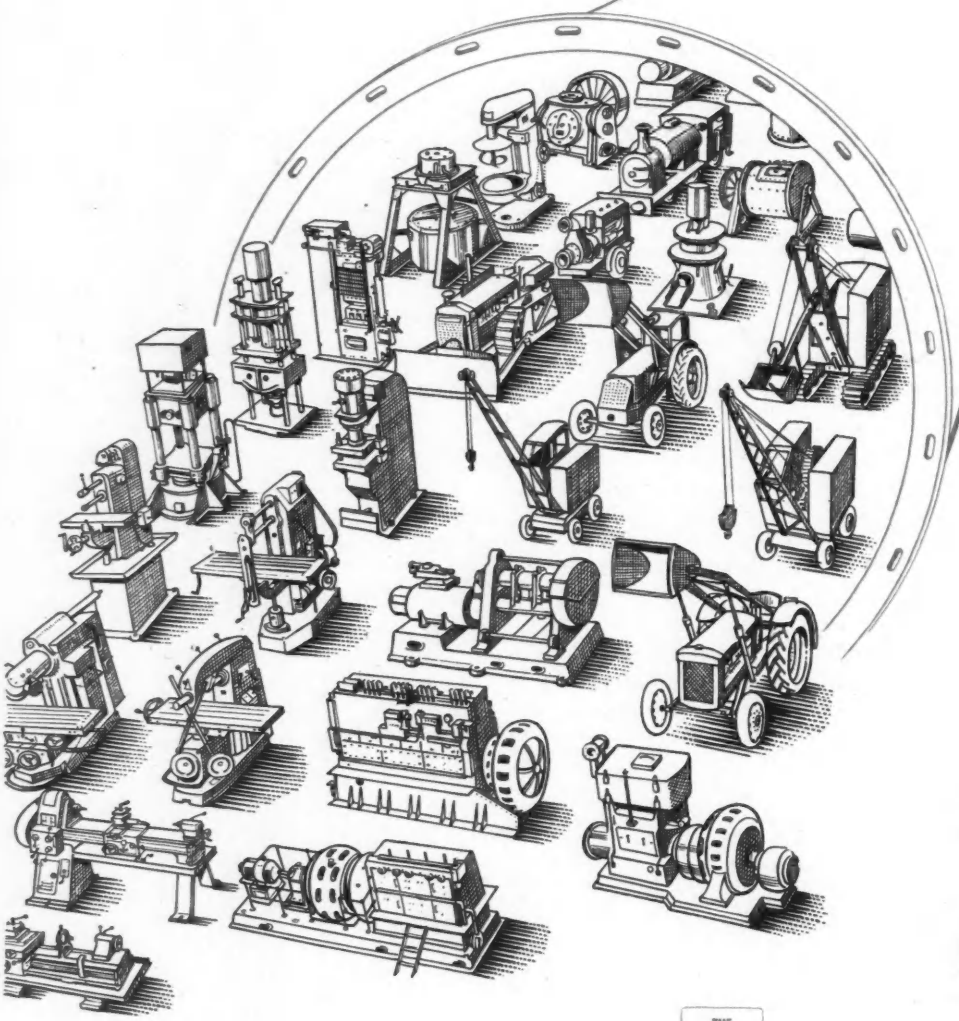
Chingford cork 'jointing' material

For less critical applications, cost may be saved by the use of this material, made alongside Langite but to a less exacting specification.
All other types of non-metallic seals, compressed asbestos fibre, impregnated paper etc. can be supplied.

CORK MANUFACTURING CO. LTD., SOUTH CHINGFORD LONDON E.4
Telephone: Silverthorn 2666 (7 lines)

LANGITE JOINTING MATERIAL
RESISTS OILS, SPIRITS, PETROL, BENZOL ETC.

PLANT AND MACHINERY



Our stocks, which are the largest in Britain, include:

Machine Tools, Power Presses and Sheet Metal Working Machinery, Hydraulic Plant, Electric Generating Sets, Electric Motors, Switchgear, Transformers, Boilers, Diesel Engines and other Power Plant, Chemical Plant, Plastic Moulding and Rubber Machinery, Track and Wagons, Tanks, Steel Sections, Tubes and Fittings, Contractors' Plant including: Air Compressors, Cranes, Locomotives, Pumps, etc., and every kind of Modern Secondhand Works' Equipment.

Industry's unfailing pipeline of Plant and Machinery

THE 600 GROUP OF COMPANIES

GEORGE COHEN

SONS AND COMPANY LIMITED

ESTABLISHED 1834

WOOD LANE · LONDON · W.12

TELEPHONE: SHEPHERDS BUSH 2070 · TELEGRAMS: OMNIPLANT, TELEX, LONDON

STANNINGLEY · Nr. LEEDS

TELEPHONE: PUDSEY 2241 · TELEGRAMS: COBORN, LEEDS

AND AT KINGSBURY (NR. TAMWORTH) · MANCHESTER · GLASGOW · SWANSEA · NEWCASTLE · BELFAST · SHEFFIELD · SOUTHAMPTON · BATH

SCP/N

THE ENGINEER

VOL. 202 No. 5253 SEPTEMBER 28, 1956

CONTENTS

LEADING ARTICLES—
Traffic Arteries in Large Towns 425
Many-Sided Technology 426
Equation of Food and Fuel 426

ARTICLES—
Basic Automatic Indexing Machine. (Illus.) 450
Centrifugal Pumping Set. (Illus.) ... 449
Channel Cable 433
Commercial Motor Show. No. II. (Illus.) 430
Engravings of 1876 435
Inauguration of Glasgow's West Main Waterworks 427
Institution of Locomotive Engineers ... 427
Launch of "Mayflower II"... 427
London Transport in 1955 427
Mechanical Engineering Research Centre. (Illus.) 447
Notes on the Brittle Fracture of Steels. (Illus.) 443
Polymer Deposition 434
Spline Rolling. (Illus.)... 450
Strength of a Tube under Local External Pressure. (Illus.) 428
Urban Motor Roads. No. I. (Illus.)... 440
100 Years Ago 427

METALLURGICAL TOPICS 436

CONTINENTAL SECTION—
Glockner - Kaprun Hydro - Electric Scheme. No. III. (Illus.) 452
Motorised Glider. (Illus.) 454

AMERICAN SECTION—
Work of the U.S. Atomic Energy Commission. No. I. (Illus.) 455

LETTERS AND LITERATURE 438

NEWS AND NOTES—
British Patent Specifications. (Illus.)... 459
Catalogues and Brochures 460
Forthcoming Engagements 460
Industrial and Labour Notes... 451
Personal and Business 458

TRAFFIC ARTERIES IN LARGE TOWNS

The stage has just about been reached in this country, belatedly, when public opinion accepts that motor roads are an urgent need. In fact, construction on a modest scale of the first one recently started. The British Road Federation has laboured very hard to encourage such an attitude, but has now turned its attention to attacking the heart of the matter, which is that of the motor road in an urban area; the Federation's conference on urban motor roads, which was held last week, allowed a full discussion of that problem. It is in the heavily populated cities and suburbs where such roads are most urgently needed, and where they are most difficult to provide, but public opinion is apparently not yet intelligently aware of this dilemma. There was obvious vacillation in the minds of some of the British speakers at the conference. They could not reject the urban motor road, but they baulked at the difficulty of providing it. The case for it rests on higher traffic capacity for the space taken up than any other form of road or rail track (that is, on the best utilisation of valuable city land), economic gain for the traffic, and significant reduction in accidents. The Los Angeles authorities sum up the matter thus: "Urban freeways carry three times the volume twice as fast at one-fifth the accident risk, compared with surface arteries, and the public clamour for more." The architectural appeal of such roads can also be attractive, if the design is good. Those speakers with most experience of them were generally their most enthusiastic champions. There were really two separate cases made against urban motor roads. First, that they were too expensive and would cause intolerable disruption of a city when they were built; the conclusions on economy and safety were then questioned to lend support to this attitude. The second case acknowledged the force of the arguments for the urban motorway, but suggested that such excellent routes "generated" traffic and attracted it like wasps to a honey pot. Then, when the central area was reached, traffic would be debouched into it at such a rate that congestion would be inevitable. Congestion in American cities was brought in as evidence by this school of thought.

The second argument does not, of course, specifically state that urban motor roads are unnecessary; rather the contrary. If road traffic is to have anything approaching a satisfactory track to travel on, there is no practicable alternative, when the evidence is examined. Messrs. Glanville and Baker pointed out that half the vehicle mileage in this country occurs in built-up areas (that is presumably, in relatively short lengths of crowded roads) and 75 per cent of accidents occurred in those areas. Other forms of road improvement offered only limited possibilities. Sir Herbert Manzoni urged that it would be foolish to have long-term plans which did not assume greatly increased numbers of road vehicles, and the present density of one vehicle to three inhabitants obtaining in the United States, was, he considered, a figure which would be reached in this country. German experience of the early autobahn network is also relevant. It was pointed out that the "outer ring" principle of by-passing towns was used, but has proved a failure and the outer ring roads carry little traffic. A town as small as Baden-Baden, which has a population of about 40,000 is now to have a motorway piercing right into its centre. Evidence for the need for urban motor roads, does, it seems, amount to an unanswerable case, especially from the engineering point of view. But there are other factors less clear, and since the whole life of a city is involved, engineering problems are not alone—sociological, commercial and architectural factors are all involved. Should private cars be banned from the central district, and rapid public transport services provided to complete the journey from peripheral car parks to the centre? This view was argued at the conference by Mr. A. G. Ling, but was unacceptable to other speakers. Our article in last week's issue on "Parking in the U.S.A." is relevant. Clearly, the motorway needs to be related to more general concepts of town planning; every large town is a special problem and would, presumably, need a unique solution. But questions of principle are still blurred. Is transport —and the road is a part of transport—to remain a service, which must be provided on the scale of public demand, or is some restriction, some juggling with parking and toll costs, or even prohibition, acceptable, once the urban network is in existence? Or will future rebuilding in cities group the centres of activity into pedestrian enclaves, skirted by car parks and motor roads?

On the whole the conference gave no clear-cut solution, but at least it allowed a clear statement of the problem. That is a good first step. The question is not whether urban motor roads are needed, but how to fit them in most efficiently with the overall planning of the city. Another point is clear. One urban motorway, or one system large enough to be properly analysed, is an urgent and essential need for London. With experience of its operation, solutions of these controversial points will follow. The town planning problems of the motor car age are only just being realised. We saw recently a proposal for the city centre of Doncaster, which appears to take adequate measures for cars and road safety. Realisation of such a plan would be indeed a big step forward. Again, one of London's most imaginative architectural proposals—the Barbican scheme —was rejected because it would increase traffic congestion. These urban arteries

are obviously the fundamental first step in city planning. The time is past for the academic proposal of a possible urban route, as Messrs. Glanville and Baker described in their paper. No practical advance is achieved by this plan, which is not considered in detail. Nor was any advance noted in origin and destination surveys, which are considered essential preliminaries to a well-conceived scheme. The strangulation of the metropolitan area needs relief, with a pilot scheme ; when it is in use it will be possible to have a second conference on urban motor roads, a conference whose keynote will be fructification rather than frustration.

A MANY-SIDED TECHNOLOGY

We have pleasant memories of an evening last month spent at St. Catherine's College, Cambridge, where the Institute of the Motor Industry was holding its Summer School. After dinner, the students, who had devoted the day to lectures on law, management, or kindred subjects, renounced the warmth and moonlight of the evening to hear a technical discourse. This proved to be one of those occasions when the lecturer may descend from the rostrum, but must then run a gauntlet of eager questioners.

The motor industry, in its relatively short life in this country, has developed unlike other major engineering industries. Instead of selling to a well-defined group of customers, such as air lines or civil engineering contractors, it deals with a host of buyers, including its own suppliers, and also manifold purchasers of only one unit of its product. The result is that, in effect, it discharges the function of a consulting engineer ; it requires many of its members not only to know their own goods, but to study and understand the work of the oil, electrical, tyre and other manufacturers, and also to appreciate and advise upon the requirements of the prospective purchaser. This is a task which may have been possible in the past—the struggle for survival among the highly varied motor vehicles of the late 1920s was so onerous as to narrow down the species to a remarkable uniformity—but it shows signs of becoming beyond the powers of any large number of men. The facts that speed and reliability are now taken for granted in cars, and more elusive qualities such as good handling on bad surfaces are sought, that lubricants, additives and surface treatments are proliferating, that high taxation is calling for ever increasing engine efficiency with lower maintenance costs, must expand and diversify the activities of the engineers. One small example of this effect we describe in this issue : an original and attractive approach to the production of the half-shaft that engineers for decades have used—and cursed when the sheared stump stuck in the differential—has led to the more easy manufacture of a finished product that may banish failures of a hitherto critical component. And this new technique poses far fewer problems than, for instance, the adoption of steel-cord tyres, or the petrol injection systems already established abroad. More and more avenues of advance are opening before the engineer—and already we are forced to wonder how many of our engineers have, for example, driven dead rear axles, except on heavy goods vehicles, or have explored the technique of steering a vehicle by a power control system.

At least one of our major motor manufacturers, we know, maintains a fleet of vehicles of all kinds and nationalities. This, while an expensive investment, is a valuable asset for the engineers of that firm, who are able to judge their work against the world's best for steering, ease of control, comfort, durability, economy and adaptability to extreme environments. But unless the intermediaries between the industry and its customers are similarly enabled to speak from experience, they must lose the respect and confidence that is a major asset of this curiously situated industry. Here, we would suggest, is a very practical way for the great producers to support the Institute : help it to provide a breadth of experience that cannot come from any study course. We do not doubt that the pupils would prove ready and willing to exploit the products to the full and to feed back the lessons of the users' experience.

AN EQUATION OF FOOD AND FUEL

Sir Harold Hartley, in his presidential address to the Fifth World Power Conference, drew attention to the importance of increasing the world's production of food. " We are living in an age of rapid economic expansion," he said, " more rapid in industry alas, than in agriculture, for food is the world's greatest need to-day with the perilous increase in world population—a reminder to us of the dangers that may come from an unbalanced use of man's new power to alter his environment." Later on in his address he referred to the 1957 sectional meeting of the World Power Conference, when the mechanisation and electrification of agriculture and the development of irrigation will be discussed. For these subjects, surely, are the ones in which engineers can make a direct contribution to food production ; that, at least, we would say at a guess, would have been the opinion of most of the delegates at the conference, who were, of course, engineers especially concerned with the utilisation of fuel and power ; and that presumably was the reason why those subjects were chosen for the sectional meeting.

There are, however, other important qualifying facts, including a fundamental and direct relationship between agricultural production and consumption of fuel. This is pointed out by Mr. Hugh Nicol, who is professor of agricultural chemistry at the West of Scotland Agricultural College, in his recent book *Microbes and Us*. His exposition of the theory underlying agricultural practice—for instance, how food production centres largely on the production of proteins, and hence demands leguminous crop cultivation, and how such crops can be increased by the balanced use of fertilisers to increase the nitrogen-fixing activities of bacteria which flourish in their root nodules—leads ultimately to a balance between production of food, on the one hand, and good farming practice plus the judicious use of various " artificial " fertilisers on the other. Fertilisers need, for their production, the expenditure of fuel, and thus we have in abstract the relationship stated above, which has led Professor Nicol to suggest, in referring to the Colombo plan, in which this relationship has apparently not been given prominent consideration, a paraphrase of the well-known biblical quotation thus : " The people asked for bread and were offered incombustibles."

Professor Nicol gives as an example the quantities of materials needed to utilise a million tons—say, one unit—of nitrogen, fixed, synthetically, from the air. Its use (it would yield 5½ units of nitrogeneous fertiliser) in a six-course rotation, apart from the complications of better management, equipment and so on, would also need 2½ units of potassium chloride, 4½ of superphosphate, and 6 of chalk. Fuel requirements would be about 4 units of coal for the nitrogen fixation, 1·2 units of sulphuric acid to produce the superphosphate, and a further 1·8 of sulphuric acid to form ammonium sulphate from the atmospherically fixed nitrogen (alternatively gypsum can be used here). Assuming all the materials are efficiently used, the quantities discussed would dress about 70,000,000 acres annually, and the extra production would feed perhaps 50,000,000 or 60,000,000 people. Further investigation along these lines should yield approximate estimates of direct energy demands for food production, as more intensive methods of agriculture spread, or as populations increase, and consequently the use of fertilisers increases, as it has done rapidly over the past few decades in some parts of the world. It is obviously of importance to assess the world demand for fuel, needed to ensure adequate food production, at a time when energy requirements are increasing steadily in all countries, without, at present, any signs of " saturation " being reached. Judging from the figures quoted, however, and from energy consumption at present in Western European countries (the example relates to agricultural practice in the Western European climate) it seems that the fuel needed to sustain production of food is not likely to be more than a small fraction of that used to meet other demands for energy.

A Seven Day Journal

Inauguration of Glasgow's West Main Waterworks

A NEW 36in diameter water main, 10½ miles long, from Milngavie to Cardonald, was inaugurated by the Lord Provost of the City of Glasgow, Mr. Andrew Hood, on September 20th. The ceremony, which took place at Milngavie Works, consisted of opening the 48in diameter sluice feeding the new main from Mugdock reservoir, and the unveiling of a commemorative plaque on the new straining well there. The main, which was constructed at a cost of approximately £1,050,000, provides water to new housing and industrial estates, particularly the township of Drumchapel, but will also reinforce supplies to the city and bring additional supplies to the south and south-west areas of the city. The new works comprised: the driving of ½ mile of tunnel at Milngavie through hard whinstone and sandstone rock without the use of explosives; construction of intake works and a straining well; laying cast iron and steel pipes of 36in diameter for 10½ miles; a reinforced concrete subway under the Forth and Clyde Canal at Cloberhill; two steel girder pipe bridges and one reinforced concrete pipe bridge over railways, and a tunnel 340 yards long under the River Clyde from Scotstoun to Shieldhall, the shafts being 18ft diameter and 105ft deep, the tunnel 12ft in diameter. The shafts and the tunnel are lined throughout in cast iron segments. The tunnel at its lowest point is about 50ft below the river bed. The consulting engineers for the Clyde tunnel were Messrs. Mott, Hay and Anderson; the scheme as a whole was under the direction of Glasgow's water engineer, Mr. S. Canvin. The main contractors for the various civil engineering works were Kinnear Moodie and Co., Ltd., Whatlings, Ltd., and James Miller and Partners, Ltd. The Clyde tunnel accounted for a third of the cost of the whole scheme and was characterised by the fact that its route had to be fixed from surface conditions and was hardly influenced by the geology of the river bed. Generally speaking, silt was encountered, necessitating high-pressure compressed air working, with rock about 100ft below ground level.

Institution of Locomotive Engineers

FOR his presidential address to the Institution of Locomotive Engineers on Wednesday, September 26th last, Mr. J. F. B. Vidal took for his subject "The Institution and its Members." He dealt with the early days of the institution, its difficulties, and the work done by the early members. Of the future of the institution Mr. Vidal said that much voluntary effort and the strong support of all members was definitely needed to maintain and increase its stature. The wide field which had been covered by papers indicated clearly the sensitivity of the Council to the varying interests of members and how it encouraged the dissemination of knowledge in a most comprehensive manner. He went on to say that the quality of the institution depended upon the quality of its members, and suggested that consideration be given to adding more lustre to their engineering endeavours and a greater awareness of political influences affecting the welfare of the profession. It was Mr. Vidal's impression that many members holding important appointments had been so engrossed in their problems and so fascinated in engineering generally that they seemed to have had little time to spare for other interests. Others seemed too little interested in administrative matters to become eligible for the higher managerial appointments. If some of the engineers in the past had been more politically minded in demanding from those in financial control a greater share of finance in support of engineering developments, progress might have been easier. Mr. Vidal went on to say that members individually should become more assertive and be more interested in administrative activity, deal with engineering problems with a wider view and, where possible, encourage the non-engineer to be more familiar with engineering problems in general.

The Engineer

100 Years Ago

(SEPTEMBER 26, 1856)

"THE NEW BRIDGE AT WESTMINSTER"

"A few days since, by direction of the assignees of Mr. C. J. Mare, Mr. Horsey, the auctioneer, offered to public auction, at the King's Arms Hotel, Bridge Street, 235 blocks, slabs, and landings of Cheesewring granite, Bramley Fall, and Bradford stone, cast iron piles, cement, and other articles, originally supplied for the construction of the new bridge at Westminster, but not now required by the commissioners. The sale was attended by about thirty persons, contractors and others, and the granite and stone realised from about a fourth to a third of the market price, and the cast iron piles sold at £3 10s. per ton. The auctioneer, in answer to a question, said the Government would be only too glad to get rid of the blocks, and would give every facility for their removal."

"WEIGHING MACHINE AT THE G.P.O."

"On Monday, by order of the Board of Works, several men were employed at the General Post Office in St. Martins-le-Grand in digging up the soil to a considerable depth opposite the Superintendent's office, for the purpose of fixing a gigantic weighing-machine, upon an entirely new principle. The object of this extensive work is to enable the Post Office authorities to weigh *en masse* the letters and newspapers sent daily from the office to the provinces, a work now done in detail, at much cost of time to the duty. When it is borne in mind that not less than 71,000,000 of newspapers per annum pass through the Post Office, and that the average weight of each is not less than three ounces, and that the number of 'book packets,' exclusive of newspapers, is at about the rate of 1,400,000 per annum, being an increase of 273 per cent on the number in 1854, and that the average weight of each packet is from 10 oz to 4 oz, it is quite clear that the establishment of the mechanical appliance of a weighing-machine, on a large scale, in such an important department, must prove a great acquisition, and greatly facilitate the duty at the time when the moments are, officially, of the greatest possible value."

Launch of "Mayflower II"

EARLY on the morning of September 22nd, the second "Mayflower" was launched, with appropriate seventeenth century ceremony, by an American airman, Reis L. Leming, G.M., from the yard of the builders, J. W. and A. Upham, Ltd., of Brixham. The scheme to build a replica of the ship which sailed from Plymouth in September, 1620, was started some ten years ago, and the design and constructional drawings have been produced by Mr. W. A. Baker, an American naval architect, following years of research into the design of early seventeenth century ships. Based upon old records the dimensions of the second "Mayflower" were determined at length of keel to back of main post, breadth within the plank 25ft, and depth to the breadth 12ft 6in, and according to the tonnage rule of 1582 the ship will be of 181 tons burden. Most of the timber, including the keel, ribs and hanging knees are of Devon oak, but for the masts and spars the timber, mainly Oregon pine, has come from Canada. The design calls for a three-masted rig and the rigging plan has been worked out on a 5ft model. All the standing and running rigging and the working ropes are of lightly tarred Squadron Italian hemp, made in the ropewalks of the Gourock Ropework Company, Ltd., to the specification of the period. The suit of sails for the ship are of flax sailcloth, supplied by Francis Webster and Sons, Ltd., Arbroath, complete with boltrope at the head and foot of each sail. The ship, of which the keel was laid on July 28, 1955, is expected to sail from Plymouth on April 2nd next year, and arrive at Plymouth, Massachusetts on May 30th, under the command of Commander A. T. Villiers, and manned by a complement numbering twenty-one and carrying thirty passengers, many of the crew and passengers being descendants of the original Pilgrim Fathers.

London Transport in 1955

THE London Transport Executive has published a review of its operations during 1955. One of the principal points emphasised in it is the "gradual but steady decline taking place in the total number of passengers using London bus, coach and underground services." The review shows that the number of passengers carried last year was 4096 million, or 2½ per cent less than in 1954 and 10 per cent less than in 1950. The number of passengers travelling by London Transport and British Railways' suburban services is, in fact, back to much about the pre-war volume. But the reduction in the total volume of traffic has not been evenly distributed, the "rush-hour" traffic having been affected hardly at all. The review points out that this state of affairs is creating added difficulties for London Transport because the number of vehicles and staff employed is governed by peak-hour demands, and off-peak traffic revenue is needed to help cover costs of vehicles and staff which must be provided to cater for the peaks. The review understandably comments on traffic congestion in the area covered by London Transport, and quotes figures to show that buses do not contribute to London's increasing street congestion. A bus, it is stated, occupies only one-fortieth of the road space of a private car in proportion to the number of passengers carried, and buses constitute only 13 per cent of the total London traffic. London Transport, the review says, "will continue to agitate for the removal of obstacles which prevent the circulation of buses in the streets of London." A special survey of delays encountered by buses on a congested central area section showed that the average journey time had increased by 7 per cent since 1952. The delay, it is stated, was due almost entirely to increased waits at traffic lights caused by congested and slower moving traffic.

Strength of a Tube Under Local External Pressure*

By G. R. HIGGINSON†

This article is concerned with structural elements which are only required to withstand one application of a system of loading, so the aim is to find the magnitude of such a loading system which will cause the onset of major permanent deformation. Provided the applied load does not achieve this value, no damage will be done, but, of course, the structural element would probably not endure a large number of applications near the critical load, since each of these may cause yielding in much of the element. A long tube subject to external pressure over a short, finite length is considered: a work method is used to obtain an approximate solution.

Assumptions

FIRST must be defined the assumptions on which the analysis is based.

(*a*) By "strength" is meant the load at which major permanent deformation commences.

(*b*) The material is an "ideal plastic" material:

(*i*) The yield point is sharp and there is no work-hardening. It will be assumed in addition that the material is rigid up to the yield point.

(*ii*) It is incompressible.

(*iii*) It obeys the Levy-Mises stress-strain relations,

$$\frac{d\varepsilon_1}{\sigma_1^1}=\frac{d\varepsilon_2}{\sigma_2^1}=\&c.\ddagger$$

where

$\sigma_1, \sigma_2, \sigma_3$ are the principal stresses.

$\varepsilon_1, \varepsilon_2, \varepsilon_3$ are the principal strains.

$\sigma_1^1=\sigma_1-\sigma$, &c.

$\sigma=\frac{1}{3}(\sigma_1+\sigma_2+\sigma_3)$

(*iv*) It obeys the von Mises yield criterion.

These are the usual assumptions in the simple theory of plasticity and there is ample experimental evidence to show that the strength of a structural element made of such an ideal material is very close to that of a similar element made of a ductile metal with the same yield strength.

Analysis

The loading condition examined is shown in Fig. 1 and it is our object to find what pressure will cause plastic deformation. (Although only an external pressure is considered here, the modification required for consideration of an internal pressure is trivial.) The tube will yield only over a part of its length, l, and since the remainder of the tube is rigid, the plastic region will be, in effect, a tube of finite length, built in at the ends and loaded over a short length at the middle. See Fig. 2 (*a*).

One of the difficulties of analytical work in the plastic range is that the fundamental equations relate not to the total strains but to the increments of strain taking place at any one stage. The equations can only be applied to total strains if the material is rigid-plastic and if the ratios of the principal

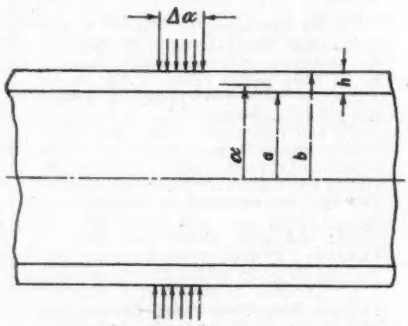


Fig. 1—Loading condition imposed on the tube

stresses and hence of the strain increments, remain constant throughout the deformation. In the present problem the stresses will remain constant until the distortion is so great that the whole geometry is changed. It is permissible, therefore, to employ the "total strain" theory instead of the theoretically correct "incremental strain" theory, since in this case the two are identical.

In a solid material deformed by forces which set up a system of principal stresses ($\sigma_1, \sigma_2, \sigma_3$) the work done per unit volume is given by the integral

$$\int(\sigma_1\, d\varepsilon_1+\sigma_2 d\varepsilon_2+\sigma_3 d\varepsilon_3) \quad . \quad . \quad . \quad (1)$$

through the changes in the principal strains ($\varepsilon_1, \varepsilon_2, \varepsilon_3$). It can be shown that for an incompressible material deformed in such a way that the ratios of stress and strain remain constant and satisfy the Levy-Mises relations, expression (1) is equal to

$$\int_0^R S\,dR \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where

$$S=\frac{1}{\sqrt{2}}\sqrt{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}$$

and

$$R=\frac{\sqrt{2}}{3}\sqrt{(\varepsilon_1-\varepsilon_2)^2+(\varepsilon_2-\varepsilon_3)^2+(\varepsilon_3-\varepsilon_1)^2}$$

For a plastic material deforming according to the yield criterion of von Mises, $S=Y$, where Y is the yield stress in simple tension or compression. Thus for Y=constant, expression (2) reduces to an integral involving only the strain function.

In this problem the tube sustains an external pressure p over a length $\Delta\alpha$, where α is the mean radius of the tube; h is the wall thickness. The radial deflection, which

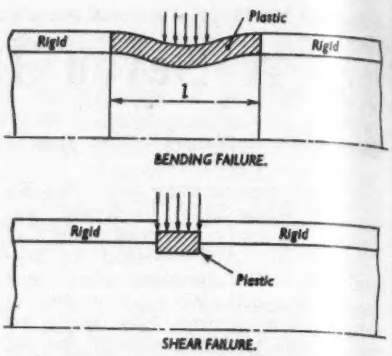


Fig 2—Form of (*a*) bending failure. (*b*) Shear failure

varies along the length, is denoted by the symbol U and cylindrical co-ordinates (r, θ, z) having axis along the axis of the tube are used. Transforming the co-ordinates and employing the incompressibility condition of plastic flow, we obtain

$$R=\frac{2}{\sqrt{3}}\sqrt{\varepsilon_\theta^2+\varepsilon_\theta\varepsilon_z+\varepsilon_z^2+\tfrac{1}{4}\varepsilon_{rz}^2} \quad . \quad . \quad . \quad (3)$$

since by symmetry shear strains other than ε_{rz} are zero. Using the arguments employed in reference 1 we achieve the approximate relation

$$R=\sqrt{\varepsilon_\theta^2+\tfrac{4}{3}x^2\left(\frac{d^2U_b}{dz^2}\right)^2+\tfrac{1}{3}\left(\frac{dU_s}{dz}\right)^2} \quad . \quad . \quad (4)$$

where x is measured in the radial direction from the central surface of the tube and

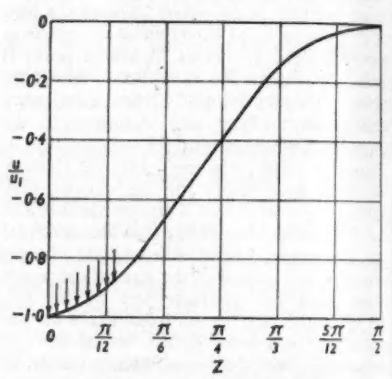


Fig. 3—Typical shape of deformation

U_b and U_s are those parts of the deflection due to bending and shear.

It is shown in the same reference that for this type of structure shear and bending failures can be treated separately, such that shear deformation can be neglected unless

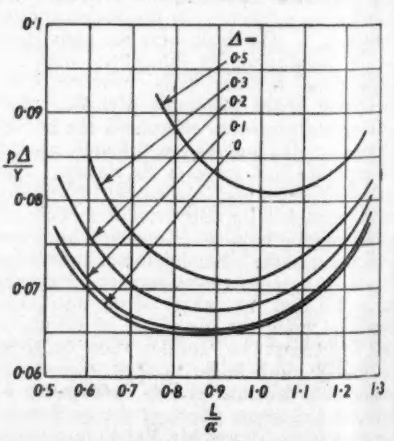


Fig. 4—Variation of $\frac{p\Delta}{Y}$ with $\frac{L}{\alpha}$ for various values of Δ ($\alpha/h=10$, $\eta=0$)

* Crown copyright reserved. Reproduced with the permission of the Controller, H.M. Stationery Office.

† Armament Research and Development Establishment, Fort Halstead, Sevenoaks, Kent.

‡ *Notation.*

a, b—internal and external radius of tube.
h—thickness of tube.
I—a function of the tube geometry.
l—length over which the tube yields.
p—surface pressure.
r, θ, z—cylindrical co-ordinates.
R—a function of the strains.
S—a function of the stresses.
U—radial deflection of the tube.
U_b—radial deflection due to bending.
U_s—radial deflection due to shear.
W—work dissipated in plastic deformation.
W'—work done by external load.
x—radial co-ordinate measured from central surface of tube.
Y—yield stress in simple tension or compression.
α—mean radius of tube.
β—$\sqrt{3}l^2/2\pi^2\alpha$
$\Delta\alpha$—length of tube over which load is applied.
$\varepsilon_1, \varepsilon_2, \varepsilon_3$—principal strains.
$\varepsilon_r, \varepsilon_\theta, \varepsilon_z, \varepsilon_{rz}$—strains in cylindrical co-ordinates.
η—a parameter representing the shape of deformation.
$\sigma_1, \sigma_2, \sigma_3$—principal stresses.
$\sigma_r, \sigma_\theta, \sigma_z$—stresses in cylindrical co-ordinates.
$\sigma=\frac{1}{3}(\sigma_1+\sigma_2+\sigma_3)$
$\sigma_1^1=\sigma_1-\sigma$.

failure is primarily due to shear and bending deformation can be neglected in a shear failure. The strength of the tube is found by calculating the pressures required to cause a bending failure and a shear failure, the smaller being the estimated strength.

The first case to be considered is that in

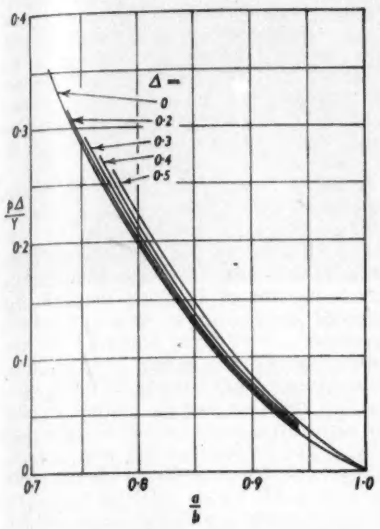


Fig. 5—Variation of $\frac{p\Delta}{Y}$ with $\frac{a}{b}$ for various values of Δ

which failure is due primarily to bending. One would expect the deflection to take a form approximating to a cosine. It can be seen if this is so by assuming a form which differs slightly from a cosine, and minimising the strength with respect to this small difference.

Thus $U_s=0$

$$U=U_b=-\tfrac{1}{2}U_1\left(1+\cos\frac{2\pi z}{l}\right)-\tfrac{1}{2}U_2\left(1-\cos\frac{4\pi z}{l}\right) \quad . \quad . \quad . \quad . \quad . \quad (5)$$

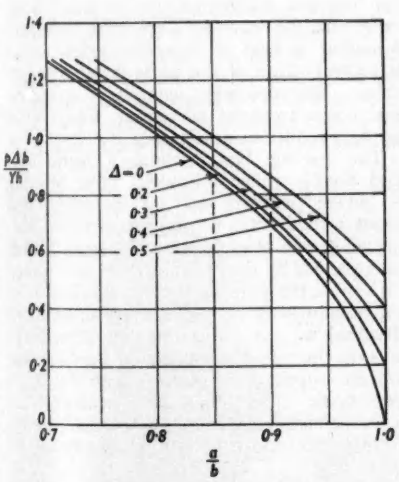


Fig. 6—Variation of $\frac{p\Delta b}{Yh}$ with $\frac{a}{b}$ for various values of Δ

We shall write $Z=\pi z/l$ and $\eta=U_2/U_1$. If η is small then the assumption of this form is justified.

Now the work done by the external pressure is :

$$W'=-2\pi bp\int_{\Delta\alpha/2}^{\Delta\alpha/2} U\,dz$$

where b is the external radius.

Integrating,

$$W'=pbu_1 l\left[\left(\frac{\Delta\alpha\pi}{l}+\sin\frac{\Delta\alpha\pi}{l}\right)+\tfrac{1}{2}\eta\left(\frac{2\Delta\alpha\pi}{l}-\sin\frac{2\Delta\alpha\pi}{l}\right)\right] \quad . \quad . \quad . \quad . \quad . \quad (6)$$

The work dissipated in plastic deformation is :

$$W=Y\int_0^{2\pi}\int_{-l/2}^{l/2}\int_{-h/2}^{h/2} R\,dx\,dz\,r\,d\theta \quad . \quad . \quad (7)$$

Putting $\varepsilon_\theta=U/\alpha$ and integrating,

$$W=hlu_1 Y\int_0^{\pi/2}\left[(1+\cos 2Z)+\eta(1-\cos 4Z)\right]\left[\sqrt{1+\left(\frac{h}{2B}\right)^2}+\frac{2B}{h}\sinh^{-1}\frac{h}{2B}\right]dZ \quad . \quad (8)$$

where

$$\frac{h}{2B}=\frac{h}{2\beta}\left[\frac{4(\cos 2Z-4\eta\cos 4Z)}{(1+\cos 2Z)+\eta(1-\cos 4Z)}\right] \quad . \quad (9)$$

and

$$\frac{h}{2\beta}=\frac{\pi^2\alpha h}{\sqrt{3}l^2}.$$

The correct procedure is now to equate W and W' and, for given values of α/h and Δ, compute the variation of p/Y with l, for a range of values of η. The minimum value of p/Y with respect to l and η is then selected as the correct one, and the corresponding values of l and η found.

Writing I for the integral in (8) and equating W and W' we obtain

$$\frac{pb}{Yh}=\frac{I}{\left(\frac{\Delta\alpha\pi}{l}+\sin\frac{\Delta\alpha\pi}{l}\right)+\frac{1}{2}\eta\left(\frac{2\Delta\alpha\pi}{l}-\sin\frac{2\Delta\alpha\pi}{l}\right)}.$$

Unfortunately, I must be obtained numerically. This is laborious, but presents no difficulty. For the special case of Δ very small,

$$\sin\frac{\Delta\alpha\pi}{l}\approx\frac{\Delta\alpha\pi}{l}$$

and (9) simplifies to

$$\frac{p\Delta b}{Yh}=\frac{l}{2\alpha\pi}I \quad . \quad . \quad . \quad . \quad (10)$$

The full computation has been carried out for a range of values of α/h from 4 to 10 and Δ from 0 to 0·3. A typical deformation is shown in Fig. 3. In each case η was small (up to 0·1) and, in calculating the pressure, little error is introduced if η is neglected. The calculation can, therefore, be simplified considerably ; the labour in computing I is much reduced and the yield pressure need be minimised only with respect to l/α.

Putting $\eta=0$, we can write :

$$\frac{pb}{Yh}=\frac{I}{\frac{\Delta\alpha\pi}{l}+\sin\frac{\Delta\alpha\pi}{l}} \quad . \quad . \quad . \quad (11)$$

The variation of $p\Delta/Y$ with l/α is shown in Fig. 4 for $\alpha/h=10$ and a number of values of Δ. This shows that the external load (as opposed to pressure) which the tube can carry increases as Δ increases. The correct values of $p\Delta/Y$ (i.e. the minimum values from these and similar sets of curves) have been plotted against the wall ratio a/b (internal radius/external radius) for a number of values of Δ in Fig. 5.

$$\frac{a}{b}=\frac{\alpha/h-\frac{1}{2}}{\alpha/h+\frac{1}{2}}.$$

We must now examine the possibility of a shear failure at the end of the loaded section. Bending deflection is now neglected and an estimate of the shear strength is found by taking as the form of deflection a large shear displacement at the ends of the loaded region and a constant circumferential deflection along this region, the remainder of the tube being rigid. See Fig. 2 (*b*).

Equation (4) gives :

$$R=\sqrt{\left(\frac{U}{\alpha}\right)^2+\tfrac{1}{3}\left(\frac{dU}{dZ}\right)^2}$$

since $U_b=0$ and $U_s=U$.

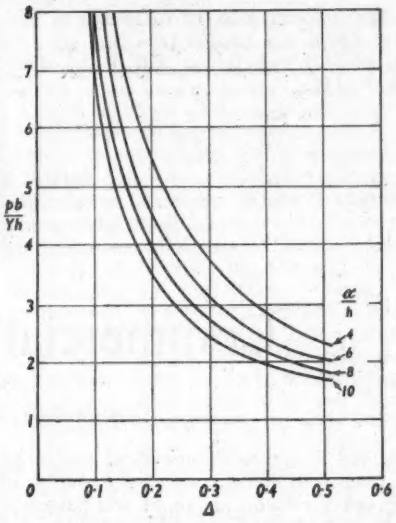


Fig. 7—Variation of $\frac{pb}{Yh}$ with Δ for various values of $\frac{\alpha}{h}$

As before,

$$W=4\pi\alpha Y\int_0^{l/2}\int_{-h/2}^{h/2} R\,dx\,dz$$

$$=4\pi\alpha hY\int_0^{l/2} R\,dz \quad . \quad . \quad . \quad (12)$$

In this case, $l=\Delta\alpha$.

Now, from $z=0$ to $z=l/2-\delta z$, $dU/dz=0$, and $U=-U_c$, constant, and from $z=l/2-\delta z$ to $z=l/2$, $dU/dz\geqslant U/\alpha$, where, of course, $\delta z\to 0$,

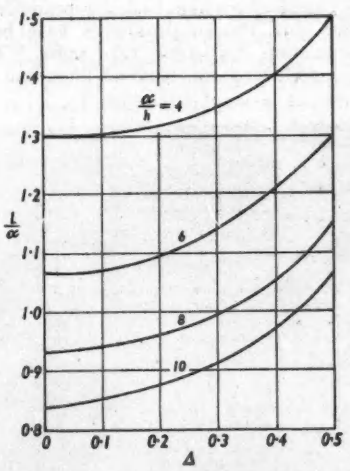


Fig. 8—Length of tube over which yielding occurs

So

$$\int_0^{l/2} R\,dz=\int_0^{l/2-\delta z}\sqrt{\left(\frac{U}{\alpha}\right)^2}\,dz+\int_{l/2-\delta z}^{l/2}\frac{l}{\sqrt{3}}\sqrt{\left(\frac{dU}{dz}\right)^2}\,dz$$

$$=U_c\left\{\frac{l}{2\alpha}+\frac{1}{\sqrt{3}}\right\}.$$

taking the appropriate square root in each term to make the plastic work positive throughout.

The work done by the external load is :

$$W' = 2\pi blpu_c \quad . \quad . \quad . \quad . \quad (13)$$

Equating W and W',

$$\frac{pb}{Yh} = \left[1 + \frac{2}{\sqrt{3}\Delta}\right] . \quad . \quad . \quad . \quad (14)$$

The pressure must be calculated in each case and if it is smaller than that given by (9) or (10) then failure will be by shear. From (14),

$$\frac{p\Delta b}{Yh} = \Delta + \frac{2}{\sqrt{3}} = \Delta + 1 \cdot 155$$

In Fig. 6 $p\Delta b/Yh$ for bending failures is plotted. It can be seen that for wall ratios greater than $a/b = 0 \cdot 74$, a shear failure cannot occur, unless the wall thickness under the load is substantially smaller than elsewhere. Even for small wall ratios (i.e. thick walls) a shear failure can only occur if Δ is very small, which will seldom be the case in practice. The type of analysis used in this note is probably not applicable to cylinders which are thicker than wall ratio about 0·75, so it seems safe to neglect shear failures altogether.

The extent to which the pressure sustained increases, as the width of application decreases, is shown in Fig. 7, where pb/Yh is plotted against Δ for a number of values of a/h. For a distributed load, $pb/Yh = 1$, so this quantity tends to unity as Δ increases. Finally, the length of the tube over which yielding occurs is shown in Fig. 8. This length is very roughly equal to the radius of the tube.

REFERENCES

[1] Christopherson, D. G., and Higginson, G. R., 1954, *Journal Mech. Phys. Solids*, Vol. II, 217.

[2] Hill, R., 1950, *Mathematical Theory of Plasticity*, O.U.P.

Commercial Motor Show

No. II

(*Continued from page* 394, *September* 21*st*)

IN the first part of our show report we dealt with some interesting examples in the heavy category of goods and passenger vehicles made by Leyland Motors, Ltd., and by the A.C.V. group of companies. Lack of space prevents us from describing in full more vehicles of this particular class, the more as the majority of these vehicles differ in details only from those seen at previous exhibitions. We should like, however, to mention a few models which, though basically not novel, are making their first public appearance at this year's show.

At the stand of Atkinson Vehicles, Ltd. we noticed a twin-steer six-wheeled lorry having a licensing weight of 5 tons and designed to accommodate a 20ft body for loads of 9 to 10 tons. It is powered by a 94 h.p. five-cylinder, Gardner engine and is equipped with hydraulic servo-assisted brakes. Another Atkinson vehicle, a double-deck chassis also makes its first appearance at Earls Court, though prototypes have been in operation for some two years. The frame, following conventional lines, can be supplied in either 27ft or 30ft overall form and is also suitable for single-deck operation. It is powered by a 112 h.p. six-cylinder Gardner engine, driving an epicyclic gearbox through a fluid flywheel which incorporates a centrifugal clutch. The gear change is effected by electro-magnetic selection and hydraulic operation of the gear brake bands.

At the stand of Dennis Bros., Ltd., the "Loline" double-deck low-height bus seems to interest a considerable number of visitors. The "Loline" is a 30ft version of the well-tried "Lodekka" model, originally built by Bristol and Eastern Coach Works and now being built under licence by Dennis Bros. The chassis and the front and rear suspension follow conventional lines. In order to provide the required low floor level while still maintaining a central gangway, the transmission line has been located very close to the nearside chassis length member. The engine gearbox unit is mounted at an angle relative to the vertical centre plane of the chassis and the torque from the six-cylinder Gardner engine is transmitted through a twin-plate dry clutch to a five-speed gearbox with indirect gearing in every ratio. The companion flange for the propeller shaft is splined to the lay shaft, resulting in an offset of 5¾in for the transmission line without the need for a transfer box. The first and second shafts of the three-piece propeller shaft are also arranged at an angle, thus keeping the whole transmission close to the chassis length member without inducing any excessive angular movements in the individual universal joints. The rear axle, similar to that of the A.C.V. "Bridgemaster," has a dropped centre piece with a spiral bevel primary reduction gear at the nearside and two spur wheel final drive casings at each end of the axle assembly.

Fig. 5—Morris "Minibus" has the power unit mounted between the front seats

Scammell Lorries, Ltd., a firm now associated with Leyland Motors, Ltd., shows a number of vehicles ranging from the well-known "Scarab" mechanical horse to the six-wheel drive "Super Constructor" (Fig. 6), a vehicle capable of handling unitised skid-mounted loads of up to 30 tons in oilfield operation. The "Super Constructor" very closely follows the design of the 20-ton "Constructor," exhibited at the 1954 show, and has the same engine, gearbox, transfer box, drive arrangement and drive axles as the latter. The vehicle is fitted with a 12·17-litre six-cylinder Rolls-Royce diesel engine, developing 200 h.p. at 2100 r.p.m., but can also be equipped with the latest 200 h.p. Leyland-Albion engine. The engine torque is transmitted via a single dry plate clutch and a short propeller shaft to the six-speed constant-mesh gearbox, which is fitted with a power take-off. Attached to the rear of the main gearbox is the transfer gearbox, which distributes the torque by means of spur wheels to three separate output flanges, one for the propeller shaft connection to each of the three axles. Incorporated in the transfer box is an auxiliary gear giving two speeds and a neutral in each of the gears of the main gearbox ; it also contains a dog clutch for disengaging the front axle drive.

Apart from the fact that the front axle is fitted with constant-velocity universal joints to the steered front wheels, the design of the four-star differential, the primary spiral bevel and the secondary epicyclic reduction is similar to that of the other axles, and a large proportion of the parts is interchangeable. The epicyclic secondary reduction gears are arranged on either side of the primary reduction gear casing.

The steering box contains a spiral cam and double roller follower. The steering is power assisted by air pressure and needs a hydraulic oscillation damper connected to the track arms. The front brakes are operated by air pressure cylinders mounted on top of the steering swivels, the brakes of the bogie wheels by toggle levers actuated by diaphragms. A hand-operated disc brake acts on the transmission line to the four rear wheels, which are equipped with 14·00-24 twin tyres. The "Super Constructor" has a wheelbase of 25ft, an overall length of 34ft 5in and a carrying capacity of 33 tons.

Transport Equipment (Thornycroft), Ltd., shows a six-wheel version of the four-wheel "Big Ben" (Figs. 8 and 9), the latter vehicle having proved its suitability particularly in the Middle East. It is powered by a 11·3-litre turbo-charged six-cylinder diesel engine—already seen at the 1954 commercial motor show—and has a four-speed main and a three-speed auxiliary gearbox, driving either the rear wheels only or alternatively all six wheels. Twin axles form the driving bogie, the drive being by a hypoid primary reduction with a secondary reduction by planet gears

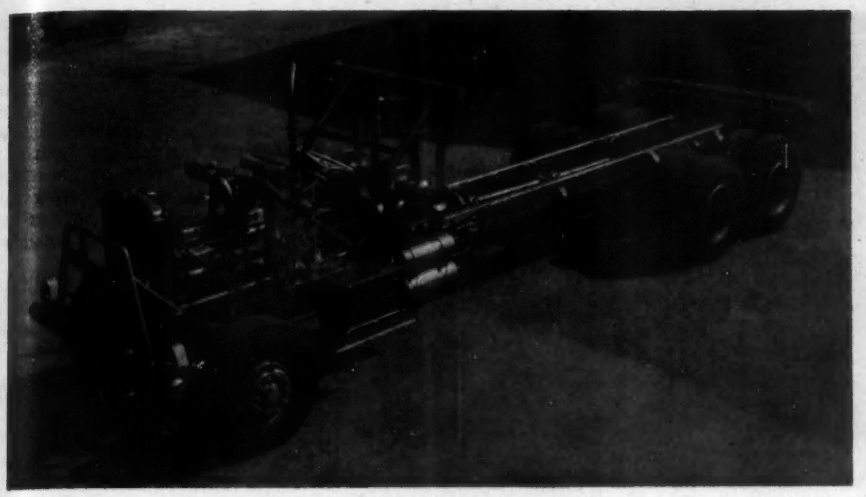


Fig. 6—Scammell "Super Constructor"

mounted inside the wheel hubs. Single tyres, 14·00–20in eighteen ply, are fitted at the front and twin tyres of the same size at the rear. The brakes are actuated by air pressure and so is the servo-assisted clutch withdrawal mechanism (Fig. 10); the power-assisted steering, however, is operated by hydraulic pressure. The chassis weighs about 10 tons, and the maximum gross laden weight is 30 tons solo or up to 50 tons with independent trailer or semi-trailer.

Turning now to medium-weight goods vehicles, we also note at the Thornycroft stand the "Swiftsure" 6-ton platform lorry, the chassis of which has been designed with an ample weight allowance for bodywork so that the complete vehicle weighs under 3 tons, thus permitting the maximum legal road speed in this country of 30 m.p.h. This favourable power-to-weight ratio has been achieved largely by using alloy steel, but weight has also been saved by a new flat-topped frame for the chassis which allows the use of a light body underframe. Other design features include a plastic cab, built on a standard cab base, which consists of a one-piece roof, rear panel and doors, all made of glass-fibre, and is 1 cwt lighter than the standard steel cab. The vehicle has a four-speed gearbox and is powered by a new 4·18-litre, six-cylinder engine, having timing gears of wrought aluminium which are claimed to be particularly silent. A new filtration system is employed whereby oil fed to the crankshaft bearings is fully filtered, but by-pass oil goes directly back to the sump without filtration.

Generally speaking, the class of medium-weight trucks, from a technical point of view, is less interesting than that of heavy goods and passenger vehicles, many of which have been designed in co-operation with big transport organisations to meet their specific requirements. The design of light and medium-sized goods vehicles is more or less standardised and follows conventional lines, any special demands of the customer as to body construction, equipment, and so on, being satisfied mainly by dealers, body-builders and similar specialised firms. Forward and semi-forward control are still preferred for trucks and tractors operating in this country. For export, especially to such overseas countries where the position of the engine next to the driver's seat might adversely affect his comfort, the demand for the cooler and less noisy cab behind the bonnet is increasing. The use of underfloor engines for goods vehicles is apparently losing ground, although the potential saving of platform space is readily admitted. The main objections to a more general application of underfloor mounting seem to come from small operators who claim that the repair and servicing of underfloor engines require specially trained personnel. They further maintain that the engine, or at least some of the more delicate auxiliaries, might be affected if abrasive or corrosive material has to be carried. Sentinel, Ltd., the pioneers of underfloor-engined lorries, are not represented at this year's show, but examples of this construction are a 4-tonner on the stand of Albion Motors, Ltd., and Atkinson, Karrier and Commer vehicles.

The Albion "Claymore" has a brewers' body with the horizontal 60 h.p., 3·85-litre, four-cylinder engine mounted amidships, thus permitting the cab to seat the driver and two mates; its low floor level provides unobstructed entrance from either side of the vehicle. With a wheelbase of 10ft, it has a turning circle of only 39ft, a decided advantage when manœuvring in confined areas.

The two amalgamated firms of Commer Cars, Ltd., and Karrier Motors, Ltd., both belonging to the Rootes Group, show improved versions of their 10-ton and 12-ton tractors fitted with the 95 h.p. horizontal 3·26-litre opposed-piston, two-stroke engine. The new models have a wheelbase of 7ft 10in and are fitted either with the Scammell automatic coupling gear or with fifth-wheel couplings for use with semi-trailers of 10-ton and 12-ton capacity. Power-assisted steering and air-hydraulic brakes, instead of vacuum-assisted hydraulic brakes, are optionally available on all models; an Eaton two-speed axle having ratios of 5·14/7·02 : 1 is standard equipment on the 12-ton tractor.

All Karrier 2-ton trucks, so far only available with 54 h.p. petrol engines, can now be fitted with a new diesel engine having a capacity of 2·26 litres and developing 50 h.p. at 3000 r.p.m. The four-cylinder engine has 84·14mm bore and 101·60mm stroke and a maximum torque of 97·5 lb-ft at 2100 r.p.m. The combustion chambers are of the Ricardo "Comet V" design; no heater plugs are provided as the engine is fitted with the C.A.V. "Thermo-start" device which ensures easy starting at low ambient temperature. The device consists basically of a valve admitting fuel at a controlled rate of flow into the inlet manifold, where it is vaporised and ignited by a small electrically-heated coil, thus preheating the aspirated air. Although the design of the engine is conventional, it is remarkable in so far as it is the only British

Fig. 7—Magirus Deutz air-cooled V-8 four-wheel-drive chassis

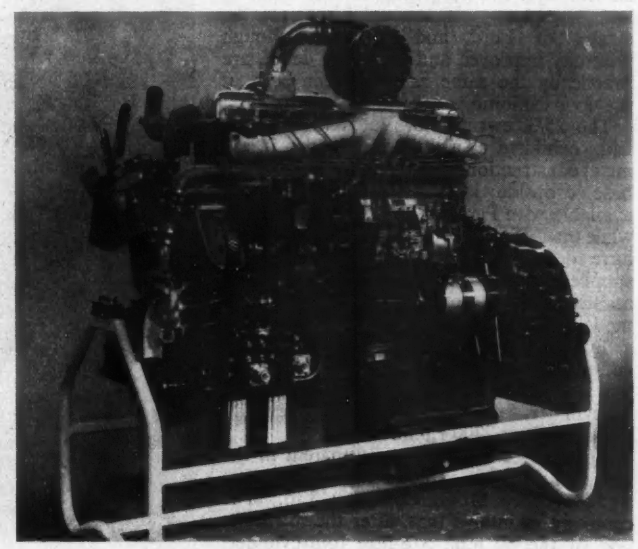


Fig. 8—Eberspacher blower on "Big Ben" engine

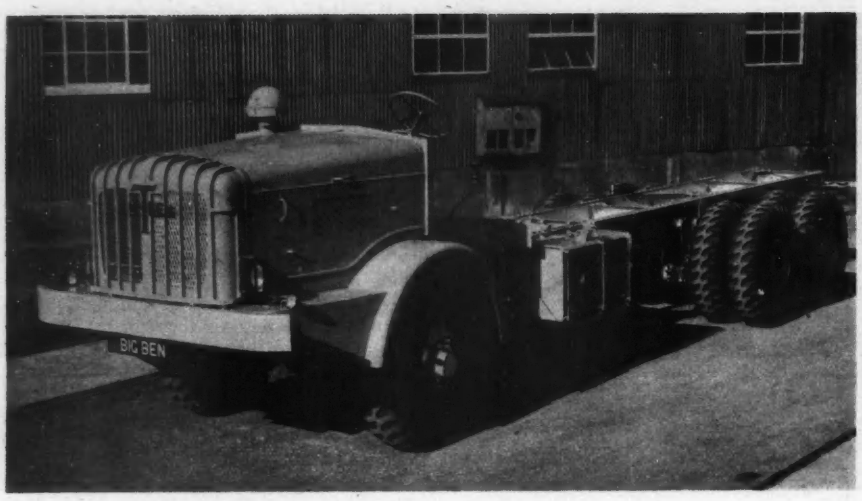


Fig. 9—Thornycroft "Big Ben" turbo-charged diesel chassis

production unit to employ a distributor fuel-injection pump as standard equipment. Details of this pump, which is being built in this country by C.A.V., Ltd., have been published in THE ENGINEER of September 14, 1956.

Most of the light and medium commercial vehicles are being made by four of the "Big Five" motor-car manufacturers, namely, Ford, British Motor Corporation, Vauxhall and the Rootes Group. Their combined output in 1955 amounted to more than 75 per cent of the total production. It is obvious that the great majority of double-purpose cars, delivery vans and pick-ups made by any of these big manufacturers closely follow the constructional principles of their particular motor-car design, utilising as far as possible the same or suitably modified components. Similar conditions apply more or less to medium-weight vehicles though in this field it might sometimes be difficult to co-ordinate the varying requirements of the customer with the rigid methods of large-scale production. In any case, the design of medium-weight commercial vehicles is largely stabilised and drastic changes of design can hardly be expected. Innovations, as far as they are noticeable, are mainly confined to improvements of units and accessories bought from outside manufacturers. In these circumstances it is not surprising that the chassis and complete vehicles exhibited at the stands of Ford and Vauxhall, though naturally improved and refined in detail, are practically the same as have been seen at previous exhibitions.

The 25/30 cwt van of Vauxhall Motors, Ltd., exhibited as a three-way loader in all-metal construction, and the 3-ton long-wheelbase dropside lorry are now optionally available with Perkins "P.4" diesel engines, while the "Big Bedford" 5 and 7-ton vehicles have deeper frame members and can be supplied with a Vauxhall-designed, power-assisted steering device. One of the 7-ton models with a 9ft 8in wheelbase, fitted with a hydraulically operated, all-steel, welded end-tipper body of 6 cubic yards capacity, was shown with the Perkins "R.6" six-cylinder, 5·56-litre diesel engine, developing 108 h.p. at 2700 r.p.m.

No changes in design are apparent in the range of medium vehicles exhibited at the stand of Ford Motor Company, Ltd. The company maintains that, after the introduction of the 60 h.p., 3·6-litre four-cylinder, direct-injection diesel engine in 1954, the demand for the "Thames" range of goods vehicles has greatly increased, and that only minor detail modifications have been considered necessary.

The British Motor Corporation, represented by Austin Motors, Ltd., and the Nuffield Organisation, has a large number of light and medium-weight commercial vehicles on show, ranging from 5 cwt delivery vans to trucks in the 2, 3, 4, 5 and 7-ton class. Since 1955, the entire range of trucks has been redesigned to give improved styling and in many cases a useful choice of power units. A new short wheelbase, 7-ton model, developed from the 7-ton long wheelbase, forward-control truck, is making its first public appearance. The chassis has a wheelbase of 10ft (compared with 12ft 6in on the 7-ton truck) and an overall length of 16ft 6in, and is available either as a chassis/cab or chassis/scuttle. The exhibit at the show is fitted with an all-steel, 6 cubic yard, end-tipping body. The power unit is the B.M.C. 5·1-litre, direct-injection, six-cylinder engine, developing 90 h.p. at 2400 r.p.m., with a maximum torque of 228 lb-ft. at 1500 r.p.m. The torque is transmitted through a dry single plate 12in diameter clutch and a four-speed, constant-mesh gearbox to an electrically controlled Eaton two-speed rear axle with a reduction ratio of 6·14/8·54 : 1, thus providing the driver with the choice of eight forward speeds. The vehicle, therefore, is equally suited to hauling heavy loads in hilly areas or to maintaining long-distance schedules on relatively fast routes. The chassis specifications include vacuum-assisted hydraulic brakes with two leading shoes on the front and one leading shoe on the rear, a large rubber-mounted centre bearing in the transmission line, and helper springs at the semi-elliptic rear springs. The unladen weight of the vehicle is 3 tons.

Fig. 10—Control valve of the "Big Ben" power-assisted clutch

Public interest at the stands of the British Motor Corporation seems to be concentrated on the recently introduced range of forward-control 15 cwt vehicles, which, of basically similar construction, are available as light van, pick-up and as 9/12 passenger bus. The vehicles, built in the Birmingham factory of Morris Commercial Cars, Ltd., are marketed both by Morris and Austin, the Morris version being known as the "J.2" series—light van, pick-up and "minibus" (Fig. 5)—the Austin version as the "152"—"Omnivan," "Omnitruck" and "Omnicoach." Apart from the slightly different front-end treatments the Austin and Morris vehicles are identical, and most of the mechanical components, such as the engine-gearbox unit, the steering column gear change, the rear axle and other parts, are either the same or suitably modified units adopted from the 1·5-litre range of B.M.C. motor cars. The four-cylinder petrol engine has a compression ratio of 7·15 : 1; it has been downrated to produce 42 h.p. at 4000 r.p.m. with a maximum torque of 64 lb-ft at 2000 r.p.m. It is mounted in unit with the four-speed synchro-mesh gearbox and the radiator well back in the integral chassis body structure between the driver's and the mate's seat, thus allowing an unobstructed entry and exit forward of the front wheels from the nearside of the vehicle. Semi-elliptic leaf springs are fitted at the front and at the rear, the front axle being of the conventional rigid beam type, and hydraulically operated two-leading-shoe brakes are used at each wheel.

The integral all-steel body, common to all models, consists of a corrugated-section pan to which are spot-welded the top-hat-section length and cross members. The cab assembly is also common to all vehicles and is welded to the forward extensions of the floor length members. The construction of the load-carrying part of the body varies in the three different models, but the roof of the van and the bus are identical, and the cab doors are designed so that they can be fitted either with hinges to the pick-up and bus or as sliding doors to the van. In addition to the cab doors on either side, a rear door is provided on the van and the bus, and a further door on the nearside of the bus.

The wheelbase of all models is 7ft 6in and the maximum permissible weight is 40½ cwt. The kerb weight varies between 23 cwt for the pick-up and 27 cwt for the small bus, allowing a clear payload of 15 cwt for the goods vehicles or seating accommodation for up to twelve passengers. The pressed steel disc wheels are equipped with 6·70-15 tubeless tyres; the spare wheel and tyre is an optional extra.

The new B.M.C. models are similar in conception and appearance to the numerous German and Italian forward-control vehicles, which, mainly because of their good space utilisation, have become quite popular on the Continent. There is little doubt that, for the same reason, they will be readily accepted in this country, and the goods vehicles have a fair chance of doing well in export markets so far dominated by Continental designs. Experience will show whether or not the

passenger vehicles with their rigid beam axles will have the riding and handling properties to compete favourably with foreign makes, all of which are fitted either with independent front or independent all-wheel suspensions.

Vehicles which could be described as the Continental counterparts of the new light range of B.M.C. can be seen at the stand of Volkswagen Werke in the form of a pick-up and a delivery van. These vehicles are based on the well-known design of the "V.W." (Volkswagen), from which they mainly differ in regard to the layout of the forward control steering and of the rear drive. The latter, while maintaining the rear-mounted air-cooled 1·3-litre engine and the gearbox drive unit, varies from the motor-car version in as far as it includes a secondary spur wheel reduction gear arranged between the swinging half-axles and the rear wheels. The all-steel body is welded to the backbone-strengthened floor structure and so is the driver's cab ; in view of the rear engine mounting the floor of the platform is higher than that of conventional vehicles, and access to the loading space of the van is through double doors either on the nearside or on both sides. The vehicles weigh about 21 cwt and are designed for a payload of 15 cwt.

Fig. 11—A Volvo truck running light with the dead axle retracted

Apart from the "V.W." there are two more Continental vehicles powered by air-cooled engines, the German Magirus "Jupiter" and the Czechoslovakian "Tatra." The "Jupiter," made by the Magirus factory of Klöckner-Humboldt-Deutz A.G., is a four-wheel drive tipper having an all-steel 5·85 cubic yards body with a forward extension which provides protection for the cab. The 10·64-litre eight-cylinder swirl chamber diesel engine develops 170 h.p. at 2300 r.p.m. and has a maximum torque of 448 lb-ft at 1200 r.p.m. The separate cylinders of 110mm bore and 140mm stroke are arranged in vee form with an included angle of 90 deg., and the fan, mounted in front of the engine and driven by a shaft and gearing from the flywheel end, supplies the cooling air to the cylinders through a duct located betweeen the two cylinder banks. The torque is transmitted via a single dry plate clutch and a six-speed constant-mesh gearbox to a two-speed transfer box with the usual provision for disengaging the drive to the front axle. Spiral bevel gears provide the primary, and epicyclic gears in the wheel hubs the secondary, reduction. The chassis weighs 5 tons and is designed for a load carrying capacity of 9 tons. It appears in Fig. 7.

One of the most interesting vehicles at the exhibition is the entirely unorthodox Czech "Tatra," which is shown in chassis form and also with a three-way hydraulic tipping body. It is a six-wheeler : all the wheels are driven and independently sprung. The frame consists of a longitudinal backbone tube enclosing the main transmission line. Each wheel is mounted on an axle tube and is linked to the tubular backbone so that it is free to pivot about the axis of the longitudinal tube member. The torque from the gearbox is transmitted from the main transmission shaft to each wheel drive shaft through individual bevel gears, the crown wheel of each drive shaft swivelling about the corresponding drive pinion on the transmission shaft.

The air-cooled 14·8-litre twelve-cylinder direct injection diesel engine also has a number of unorthodox features : the separate cylinders are arranged in vee form with an included angle of 60 deg. on a tunnel type crankcase, the built-up crankshaft running in seven roller bearings. Two fans, one for each cylinder block, are mounted at the front of the engine and are driven by duplex vee belts from a pulley on the free crankshaft end. The air intake manifolds and the injector pumps are located inside the vee and the exhaust manifolds at the outside of the cylinder banks. The engine has 110mm bore and 130mm stroke (10mm less than the Deutz-Magirus engine) and develops 180 h.p. at 1800 r.p.m. Although the engine is well designed and quite compact, the constructional effort embodied in this design seems rather excessive for a 180 h.p. medium-speed engine for a commercial vehicle.

In this connection it should be mentioned that air-cooled diesel engines in commercial vehicles are becoming increasingly popular on the Continent. They are claimed to be superior to water-cooled engines, not only with regard to weight and bulk, but also in wear resistance, as the high cylinder temperature prevents corrosion of the cylinder walls by condensation of the sulphuric acid formed in the combustion process. Considerable progress has been made lately in the reduction of engine noise by improved fan designs and by the employment of hyper-eutectic Al.-Si. alloy pistons having a low coefficient of thermal expansion and, consequently, allowing small clearances.

Holland is represented at the show by D.A.F. (Van Doorne's Automobielfabriek) showing types for payloads from 5 tons to 15 tons. A 10–15-ton model and a 6–7-tonner incorporate a D.A.F.-built Leyland engine, while a third exhibit, a 5-tonner, is fitted with a Perkins "P.6" engine.

The Swedish exhibits at the stand of A. B. Volvo, all diesel-engined vehicles of mainly orthodox design, have some interesting features which are unusual to British eyes. One of the displayed six-wheelers for 18 tons gross load has a 9·6-litre diesel engine of 150 h.p. and a five-speed gearbox ; it has one driven two-speed rear axle, and the trailing axle can be lifted by an electro-hydraulic mechanism to raise the rearmost wheels clear of the ground when the vehicle is running light, as in Fig. 11. A transverse bench in the cab behind the seats can be used as a bed by one of the crew. The other six-wheeler, fitted with a tipper body of 8 cubic yards capacity, has a double-drive bogie with a swinging beam suspension, the pivot bracket of each beam being insulated from the chassis by a pair of substantial blocks of resilient rubber. The engine of this vehicle is a turbo-charged version of the previously mentioned 9·6-litre engine and develops 185 h.p. against the 150 h.p. in its normal aspirated form.

(To be continued)

The Channel Cable

By J. H. M. SYKES

In our issue of September 7th last, page 323, we published a note announcing the decision of the Central Electricity Authority and Electricité de France to adopt direct current for the proposed cross-Channel cable connection between the electricity systems of the two countries. The background of this project is briefly reviewed below.

THE recent announcement that the British and French electricity authorities have decided to proceed with the linking of their respective networks by means of a single cable, operating on direct current, and spanning the English Channel, provides an interesting indication of the degree of faith which electricity supply engineers are now prepared to place in this system of power transmission.

At the time, in 1952, when the joint committee set up by the Central Electricity Authority (then the British Electricity Authority) and Electricité de France reported on the two years of study on this problem which it had undertaken, it appeared that they considered that there was insufficient experience in the design and operation of the necessary conversion equipment for a d.c. link of commercial magnitude.

The fact that four years later they are able to recommend a d.c. project shows how great has been the progress in this field in recent years. Briefly, this progress has taken place on two fronts, in Sweden and in Russia.

In Sweden, the very lengthy programme of valve development work which took place as a result of close collaboration between A.S.E.A. and the Swedish State Power Board, mainly at Trollhättan, culminated in the commissioning of the Gotland project in March, 1954 (on a partial scale), and in July, 1954, at the full capacity of 20MW at 100kV. This scheme employs a single cable with earth return, and the rectifier and inverter equipments (basically similar) consist essentially of two banks each of six mercury arc valves, the banks being connected in series to give 100kV. With the exception of two cable faults, due to the damaging of the cable by the anchors of ships passing across the 62-mile length of cable, the scheme has operated completely satisfactorily, and when it was taken into full commercial service in 1956, the first

result was to cheapen the cost of power on the Island of Gotland, since the less costly water power from the mainland could be used in place of the power generated on the Island by expensive imported fuel.

The present writer has been present on the Island of Gotland at times when the whole supply has been taken entirely from the d.c. cable ; and it may be of interest to note that the frequency control graph has shown a straight line at 50 c/s with not the slightest deviation apparent at any time—a better result than has ever been observed from the conventional sources of alternating current, whether controlled in respect of frequency by automatic means or by manual operation, as in Great Britain.

It is expected that further developments in Swedish application of high voltage direct current power transmission will be announced before very long ; at the C.I.G.R.E. (Paris) conference this year it was stated that it was likely that one of the 220kV, three-phase overhead lines in that country would probably be converted to d.c. working to increase its load-carrying capacity. It is probable that the increasing load on the Island of Gotland will lead to an extension of the d.c. power transmission link.

From Russia, an announcement was made this year, for the first time, that a 200kV, 30MW transmission line had been in experimental operation for the last five years over the 70-mile distance between Kashira and Moscow. In this case, two single-core cables were employed. At the C.I.G.R.E. meeting, Russian engineers also gave news of a major scheme, coupling the Donbas region to Stalingrad, on which active construction work is in progress. This overhead line will be 310 miles in length and the proposed power transmission capacity is 500MW. It is proposed also that the experience gained on the Kashira line and on the new project will be utilised in the construction of very large power, long distance, transmission lines to couple in the future hydro-electric developments in Siberia with the industrial regions in European Russia.

The announcement that the Channel cable is now to be carried out with direct current has, therefore, been made with a background of relatively limited but, nevertheless, adequate experience of the commercial operation of such systems. It was thought at one time that a major obstacle to the laying of a cable across the densely navigated waters of the Channel would be the interference to ships' compasses if single cables were employed ; and it was estimated that at full load a compass deviation of as much as 4 deg. might be caused in this way. The cable now to be laid will be made up of a single insulated core with a lightly insulated concentric sheath of sufficient current-carrying capacity to take the return current. In this way the magnetic effect on the compasses of ships will be avoided.

Details have not yet been made available concerning the mercury arc converters for the 200kV cable operation ; but it is understood that they are likely to be of Swedish design, and that they will be generally similar to those used on the Gotland project.

The economic justification for the Channel cable was fully set out in a paper by Messrs. Sayers, Laborde and Lane, read before the Institution of Electrical Engineers in 1954 ; but the statistics employed at that time have naturally changed and the savings to be achieved by the cable have consequently increased. For example, at that time it was stated that " On the basis of experience over recent years the Joint Committee (of B.E.A. and E. de F.) considered that a minimum winter diversity of 300MW could be relied on. If a 100MW interconnector were installed, each country could rely on receiving, at the time of its maximum demand, 100MW from the other country, thus making possible a reduction in the generating plant capacity otherwise necessary in each. The combined saving, at 1951 price levels, was estimated roughly at about £10,000,000, against which the capital cost of the interconnection was estimated at £4,300,000, thus showing a net saving of the order of £5,700,000." The announcement about the scheme which is now to be started, and which should be in commission in 1960, states that the interconnection capacity will be 150MW, instead of 100MW, as mentioned in 1954. The capital cost of power station plant has increased since that time to a figure of about £70 per kilowatt. It can thus be estimated that the two power stations, one in England and one in France, which the cable will render unnecessary, would now cost approximately £21,000,000. Surprisingly the cost of the cable connection is given as " about £4,000,000." This figure appears low even though the d.c. project will employ only a single cable in place of the three separate cables needed for the a.c. scheme. However that may be, the saving on the above basis is of the order of £17,000,000. The cable would thus appear to be much more economically attractive than was the case when the whole question was last discussed in public.

On the question of the operational savings to be gained, it is also likely that the increased size of the cable, together with the changes that have taken place in the incremental costs per kilowatt of energy generated in England and in France at various times in relation to the daily or seasonal peak, will result in increased savings through energy transfer. It will be recalled that the economic justification for the scheme was based on three kinds of energy exchange. First, there was the utilisation of spill energy from French hydro-electric plant, which would be exported to Britain instead of being wasted, and which would take the place of an equivalent amount of thermal generation in Britain. With a 100MW cable the saving estimated under this operation each year would amount to £100,000, and with a larger cable under the old conditions of cost of fuel this would obviously increase to £150,000. The rise in the price of coal since these figures were calculated in 1952–54 is such that considerably greater advantage could be obtained in this way.

The second method in which economic advantage could be obtained by energy transfer was in regard to hydro-electric-thermal exchanges, whereby when the French hydro-electric stations had surplus power available, France would export hydro-electric energy to Britain at the time of the daily British peak period, replacing generation by stations in Britain having the highest fuel cost per unit at that time. Britain would return this energy, with an allowance for transmission losses, during off-peak periods, on the same day, and simultaneously the production of hydro-electric energy from the French reservoir stations would be correspondingly reduced, thus preserving the French water-storage position. Again, the advantage of £150,000 to be shared between the two authorities from this method of operation would be increased with the rising costs of peak load generation on thermal stations. In addition, the capital cost figure of providing reservoir capacity on French hydro-electric projects has increased, and thus it is advantageous that more use should be made of each cubic metre of storage capacity. Although it is impossible to estimate exactly how great an increase in saving through this method of operation will be achieved by 1960, since the price levels at that time cannot be forecast, with the present uncertain economic situation, it is nevertheless apparent that any changes in price, either of fuel as a consumable item or of civil engineering cost on the capital account, must cause the cable to be of even greater benefit than was at first estimated.

The third method of benefiting from energy transfers relates to thermal-thermal exchanges, where the costs of production at any given time in the two countries would be compared and economic exchanges would be made. Under this heading, it is unlikely that price changes will make any great difference to the economic benefits to be achieved, since prices are likely to run fairly level in the two countries if statistics over the last five years are any guide ; nevertheless, the larger cable, of 150MW, should enable the previously estimated figure of £350,000 per annum to be shared between the two countries to be at least increased in proportion to the size of the new cable compared with the 100MW of the previous project.

The engineering feat of laying a power cable of this size will be watched with great interest by the many engineers throughout the world, who have in contemplation lengthy submarine power transmission links. Although the converting plant has to a considerable extent proved itself by now in commercial service, nevertheless there will be valuable and interesting lessons to be learned in the international control of one of the largest power links between countries yet installed or contemplated. With direct current the delicate frequency control necessary to maintain predetermined loadings on an a.c. cable will no longer be necessary, and thus one of the major difficulties foreseen in the operation of this new international transmission project has been removed.

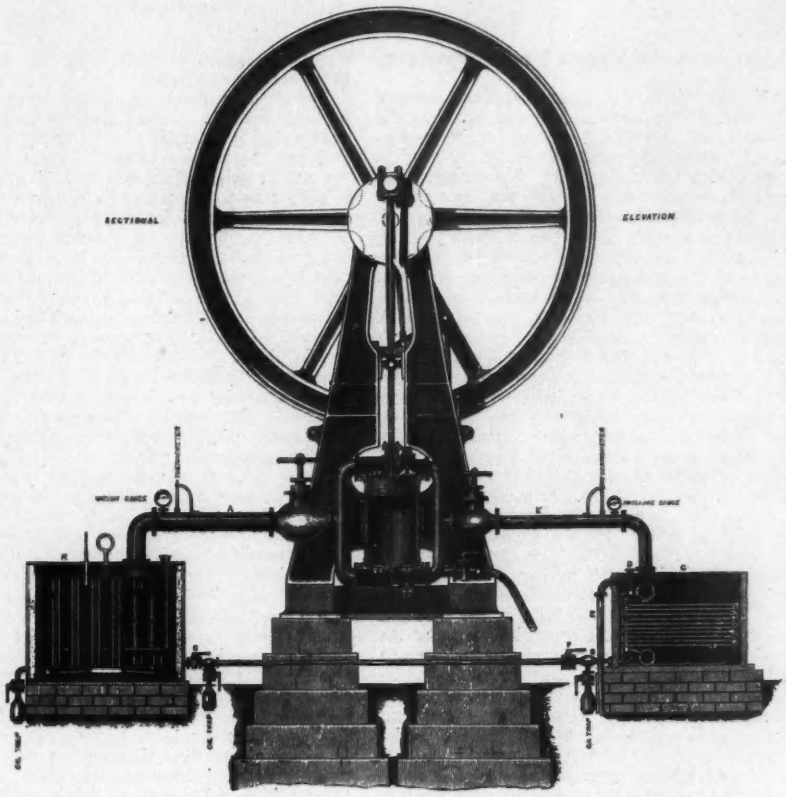
Polymer Deposition

A PROCESS capable of giving a uniform and closely controlled thickness of plastic lining to articles of complex form can be carried out in plant provided by Horwitch Smith and Co., Ltd., Pensnett, Brierley Hill, Staffs. The article is first degreased and then roughly sand blasted, though the latter process, which improves the adhesion, may not be necessary if the coating envelopes the part. The object is then heated and dipped into the Griesheim whirl sinter unit.

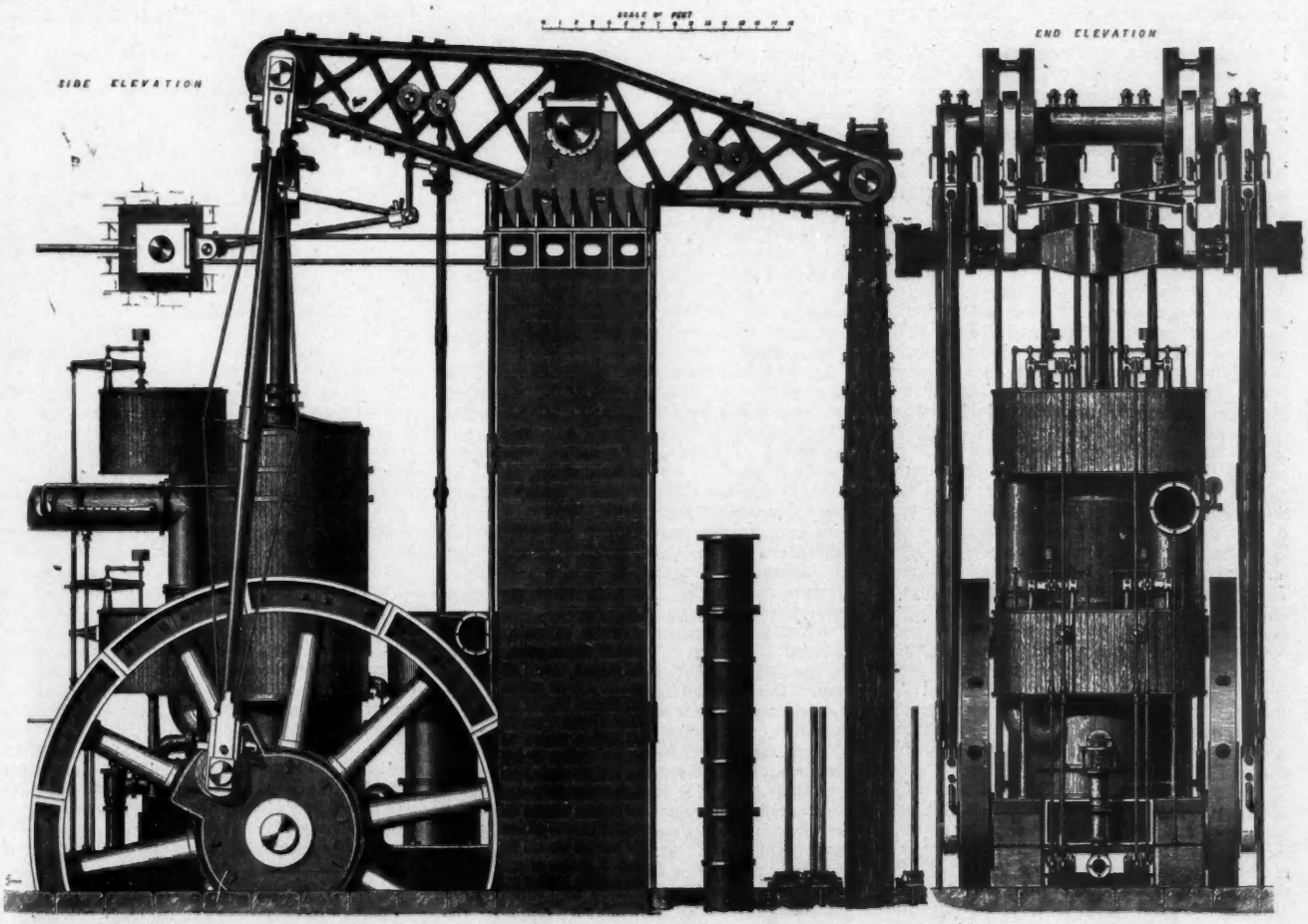
This consists of a container with a porous ceramic base, and filled with plastic in powder form. Air, or nitrogen if oxidation is to be avoided, flows through the base and " fluidises " the powder. The plastic adheres to the hot surface ; the thickness of the deposit obtained in a single immersion depends on the temperature and also upon whether it is left in for the usual thirty to fifty seconds. When the part is removed the coating appears to comprise powder particles, but the particles fuse into the lining under the effect of the heat stored in the part. If the component has much surface for its mass, this final uniformity of the lining can be achieved in an oven at 120 deg. to 140 deg. Cent. or with a soft gas flame. Specially prepared polymers must be used : the Griesheim Hostalen types include T.P.M., consisting of 99 per cent of polyethylene, and T.P. Extra, with a poly-isobutylene addition for highly stressed applications recommended for covering large areas. Both plastics are available—suffix " g "—with an additive imparting high adhesion and improved resistance to ultra-violet light.

ENGRAVINGS OF 1876

In our issue of May 19, 1876, we commented on the practical success of an undertaking, in which "a piece of artificially frozen ice had been maintained in excellent condition for skating and had been skated upon for the last four months in London." This comment concerned the "refrigerating apparatus at the Chelsea Glaciarium," an engraving of which is reproduced here (right). Our article on the subject claims that "the three essential characteristics of a Glaciarium, independently of the mechanical power, are the fluid frozen, the freezing medium, and the freezing agent. The first of these at the Chelsea Glaciarium is water, the second a solution of glycerine, and the third sulphurous acid. The sulphurous acid does not in any manner corrode the machinery, and this great advantage is due to the fact that it never comes in contact with the atmosphere."



The rotative pumping engine at the Friedenville Zinc Mines, Lehigh, U.S.A., was described and illustrated in our issue of June 16, 1876, from which the engraving below has been reproduced. The engine was designed by Mr. John West and was built by Meyrick and Sons, of Philadelphia. Our description says: "It is well known that the Cornish engine cannot be worked to any great extent expansively, unless the pits are so deep that a great mass has to be put in motion, in the shape of pump spears, etc. Now the lift in the Lehigh mines is comparatively small, and Mr. West therefore introduced the means of expansive working in the shape of two fly-wheels. It will be seen that these wheels appear comparatively small in diameter, and nothing will give a better idea of the colossal dimensions of the whole of the machinery than the statement that they weigh seventy-five tons each. The engine has a pumping capacity of 15,000 gallons per minute."



Metallurgical Topics

Impregnation in Modern Powder Metallurgy

THE technique of impregnation of one material by another has been known and practised for many years. Initially, it was used in the production of metal, the pores of which were impregnated with lubricating oil. The prototype of all such materials was probably that described in the United States Patent No. 101,863, taken out by an engineer named Gwynn, in the year 1870. This patent covered a hot-pressed tin compact containing residues from a petroleum still, and it provided, so far as we know, the earliest example of a self-lubricating journal box. A specific claim was that journal boxes so made could run at high speeds without lubrication, as the lubricant was actually incorporated in them. Some idea of the service which such bearings render in just one industry may be gathered from the remarks made hardly more than two years ago by the vice-president of the Amplex Division of the Chrysler Corporation. In a review published at the end of 1953, he said that Chrysler now carried some 20,000 different stock sizes of bearings alone.[1] He also said that the range of sizes ran from 10,000 parts to the pound to bearings weighing 250 lb apiece.

To-day, impregnation serves many purposes and is by no means the least of the methods whereby metallurgy serves engineering and the engineer. The very simple procedure patented by Gwynn was soon followed by methods involving the impregnation of a wide range of porous materials, including bronze, iron, steel and many other metals and alloys. In the earlier practice a liquid lubricant, almost invariably a mineral lubricating oil, was used and either capillary attraction or a vacuum was used to infiltrate the porous metal. From using a liquid oil it was a comparatively simple step to use an anti-friction metal in place of the oil and so provide a harder and more highly resistant lubricating surface. A tremendous variety of materials have been used and this can be emphasised by mentioning two extremes in actual use to-day, namely, the use of indium as a metal lubricant and the use of P.T.F.E. (Fluon or Polytetrafluorethylene) as a material having one of the lowest coefficients of friction known, so much so that P.T.F.E. is virtually self-lubricating.

It would be erroneous to think of impregnation as being only of service in producing methods of lubricating. A wide field of usefulness has developed in which impregnation has conferred a multitude of new or much-enhanced properties. In 1944, for example, B.P. 608,124 covered the production of electrical contact pieces consisting of loosely compacted refractory oxide (tungsten oxide, for example), which is sintered in a hydrogen atmosphere to produce a highly porous metal, and then impregnated with copper or silver. From 76 per cent of copper or 78 per cent of silver can be absorbed by the sintered parts. An extension of this procedure has been the impregnation of an iron skeleton with lead. A very widely used combination of iron is one in which a copper-iron-manganese alloy in liquid (molten) form has supplied the infiltrant.[2] There is also the use of age-hardening alloys as infiltrants and the wide range of control that is possible by careful variations in the alloys used. Another aspect of the production of infiltrated alloys, particularly those of high density, is the making use of the solubility of one metal in another; a good example is the impregnating of a tungsten skeleton with a tungsten-nickel alloy in which advantage is taken of the fact that at 1510 deg. Cent. nickel can dissolve about 52 per cent of tungsten. This has a two-fold advantage, because not only is an additional amount of tungsten incorporated in the tungsten skeleton by the infiltration with the tungsten-nickel alloy, thereby increasing its density, but the infiltrant is prevented from attacking the tungsten skeleton because it is already substantially saturated with tungsten when it penetrates the skeleton.[3]

The pre-alloyed tungsten-nickel, or preferably a compact of 52 per cent tungsten and 48 per cent nickel powder, is placed on the tungsten skeleton, the amount of the infiltrant being 13 per cent by weight of the skeleton. The assembly is heated in a hydrogen atmosphere at a little above the melting point of the infiltrant. In an actual test the liquid alloy was almost completely absorbed by the skeleton which, during the operation, underwent marked shrinkage. The final density of the infiltrated compact was 18·1 grammes per cubic centimetre, and it had a Brinell hardness of 330 kg per square millimetre. A certain amount of control of the shrinkage is possible by regulating the quantity of fines in the tungsten powder used in the production of the skeleton. The less fines present the less the shrinkage. With reduction of shrinkage the density is naturally affected also and reduced relatively with shrinkage. It is suggested that there is possibly a fruitful field for investigation into the control of shrinkage by controlling particle size on the one hand, and manipulating the content of a soluble component on the other. Superficially, it could be agreed that the effect of such factors is either problematical or mainly of too low an order to offer practically valuable results. It can be said that until actual tests are made, speculation means nothing, and modern metallurgy, not excluding powder metallurgy, can provide many examples of useful results following quite small changes in technique. There is the example of impregnating an iron compact, rather than sintering an iron-copper compact, for the latter usually has a high porosity and therefore a tendency to brittleness. If the copper is introduced by using capillary action for imbibing the copper, the mechanical properties are greatly enhanced, notably ductility.

The solubility of iron in copper increases appreciably above the melting point of copper, and it is good practice to saturate the copper with iron before using it as an impregnant for iron. Another method of ensuring filling of pore space is to use copper alloys in which the solubility of iron is markedly less. Brasses having from 10 to 20 per cent of zinc have been used. They have the advantage of much greater fluidity than pure copper and this appears to ensure more perfect filling of pores. Also, during the heating the zinc is volatilised, thus leaving an almost pure copper-iron compact. It might be said that the procedure would lead to a deoxidisation or cleaning effect on the inner surface of the pores and this does occur to a certain extent.

In addition to finding application in the impregnation of iron compacts the procedure has been widely used in producing high-tungsten alloys capable of comparatively easy and simple machining or shaping. In such cases copper has been used and it has aided in producing metal having some 83 per cent of its full density and yet capable of being drilled, milled or turned with comparative ease. Once the copper has fulfilled its purpose, its complete removal can be achieved by evaporating it in a vacuum of 10^{-4}mm mercury for fifteen minutes at a temperature of 1550 deg. Cent.

When the tungsten is used as cathodes in electrical discharge tubes this treatment ensures the pores of the tungsten compacts are maintained open. Impregnated bearing materials in which the infiltrant is Fluon have already been mentioned, but are worthy of more attention because of their unique properties and also because they possibly foreshadow a whole range of bearing types that at present have hardly passed beyond the experimental stage. These materials were described and discussed at the Powder Metallurgy Symposium, 1954, in a paper by Dr. Blainey, a preprint of which was published.[5]

In this paper three methods of impregnation are described and considered, namely, the polymerisation of tetrafluorethylene *in situ*, extrusion of Fluon into the pores of the metal, and impregnation of the sintered metal with finely divided Fluon. Of the three methods the second and third were tried and the results obtained are discussed in some detail. This is particularly useful as it is known that P.T.F.E. has poor thermal conductivity and high thermal expansion, plus a tendency to cold flow under light loads plus a tendency to change shape without the application of external force. When a porous metal is used to provide a rigid frame for the plastic which is the case, for example, with bronze, which combines strength, good heat conductivity and also stability, most of the known imperfections of P.T.F.E. are met with and nullified.

Fluon is not the only plastic that has served successfully in this field, nor, indeed, have the fields of plastic impregnation or infiltration been exhausted. There still remain very large possibilities to be explored and there is notable interest in what have been called " dry " bearings, such as have been patented by the Glacier Metal Company, Ltd.,[4] and are also discussed to some extent in the paper by Dr. Blainey.[5]

REFERENCES

[1] *Metals Review*, 1953, Vol. 26, No. 12, page 9.
[2] *Metal Progress*, 1950, January, page 64.
[3] *Powd. Met. Bulletin*, 1951, Vol. 6, No. 1, page 32.
[4] Brit. Patent 657,080.
[5] Symposium on Powder Metallurgy, 1954. Preprints published by the Iron and Steel Institute : Group III, pages 74–88.

Scaling of Cobalt-Chromium Alloys

COBALT-BASE alloys containing chromium are of special interest as possible materials for high-temperature components. The scaling behaviour of cobalt-chromium alloys has been studied by A. Preece and G. Lucas,* who reported the increase in weight of alloys containing up to 40 per cent of chromium after fifty hours' exposure in a simulated gas turbine atmosphere at 800 deg. to 1200 deg. Cent. Their data indicated a sharp rise in the weight increase for 10 per cent of chromium with a subsequent drop to a minimum at about 25 per cent and a further slight rise when the chromium was 40 per cent. Their work has been amplified and extended by the results of an investigation on the " High-Temperature Scaling of Cobalt-Chromium Alloys," by C. A. Phalnikar, E. B. Evans and W. M. Baldwin, Jr.† Ingots, 1in in diameter, of pure cobalt and of five cobalt-chromium alloys, were prepared by the induction melting of electrolytically prepared metals of 99·9 per cent purity in a zircon crucible under an argon atmosphere. The top and bottom portions of the ingots were cropped and the remainder annealed at 1200 deg. Cent. for half an hour, hot forged at 1090 deg. to 980 deg. Cent. to $\frac{1}{2}$in diameter rod, which was again annealed at 1200 deg. Cent. for three hours in an atmosphere of helium. Slices, $\frac{1}{16}$in thick, were cut from the bars, surface ground and polished to 000 paper, and washed with methanol before undergoing a continuous scaling test. The alloys contained 8·85, 12·25, 25·57, 38·33 and 48·50 per cent of chromium. In addition, there were similar specimens of metallic cobalt and polished specimens of electrodeposited chromium which had been heated at 400 deg. Cent. for four hours to remove hydrogen. The 48·5 per cent chromium alloy could not be worked and so was used as annealed in a vacuum for twenty-four hours at 1093 deg. Cent. A 63 per cent chromium specimen shattered on grinding. Each specimen was scaled in air by suspending it in a resistance-wound vertical tube furnace from one arm of a magnetically damped "chainomatic" balance, and

* *Journal of the Institute of Metals*, 1952, Vol. 81, page 219.
† *Journal of the Electrochemical Society*, August, 1956, page 429.

continuous weight measurements were taken from the moment the specimen was inserted in the furnace. The constituents of the scale formed by oxidation were identified at room temperature by X-ray examination. Whenever possible, scale layers were separated and powder samples examined by X-rays.

The scale formed on cobalt consisted of two layers ; in this there was agreement, though not quantitative agreement, with Preece and Lucas. At temperatures up to 900 deg. Cent. the inner layer was grey and X-rayed as CoO ; the outer

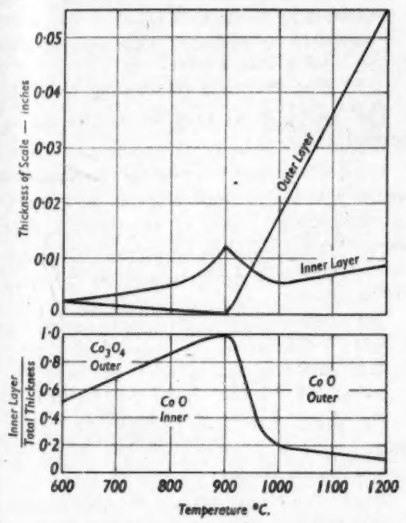


Fig. 1—Effect of scaling temperature on the thickness and composition of layers of scale formed on cobalt heated for 100 hours in air (Phalnikar, Evans and Baldwin)

layer was greyish black and X-rayed as Co_3O_4. Above 900 deg. Cent. the inner layer was a thin brown, the outer layer greyish black, and both X-rayed as CoO. The outer layer of Co_3O_4 occupied about 50 per cent of the thickness at 600 deg. Cent., but became relatively thinner as the temperature went up until it disappeared at about 900 deg. Cent. As the temperature was further increased the outer layer of CoO first appeared and then gradually increased until at 1200 deg. Cent. it occupied 90 per cent of the total thickness (Fig. 1). The square of the thickness of each layer as a function of time at 900 deg. and at 1000 deg. Cent. gave a straight line, indicating that a parabolic law of growth was followed for the individual layers. Evidence was obtained showing that the outer layer grew

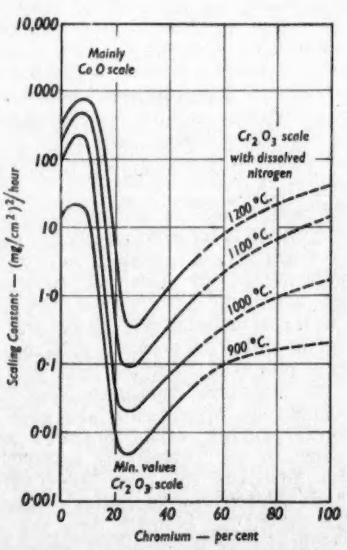


Fig. 2—Scaling constant (mg/cm²)²/hour, for cobalt-chromium alloys heated in air (Phalnikar, Evans and Baldwin)

by diffusion of cobalt ions outwards and the inner layer by diffusion of oxygen ions inwards, as previously noted by Preece and Lucas. The scale found on metallic chromium was chromium oxide, Cr_2O_3. In oxygen it consisted of chromium oxide only at all temperatures, but in air at high temperatures the chromium oxide scale contained dissolved nitrogen, or Cr_2N, also.

At any given temperature the rate of scaling of cobalt-chromium alloys at first increased with the addition of low percentages of chromium, then dropped precipitously with further additions reaching a minimum at 25 per cent of chromium. Thereafter the scaling rate again increased, approaching that of pure chromium as the upper limit (Fig. 2). Above a critical concentration of about 25 per cent the scale consisted exclusively of Cr_2O_3. Below this critical concentration, complex scales consisting of the oxides of both cobalt and chromium were formed. The formation of spinel (cobalt chromite) was observed in the complex scales, but this had no apparent beneficial effect on scaling resistance. The best resistance to scaling was associated with a scale consisting predominantly of Cr_2O_3, not spinel. In the low-chromium alloys the cobalt ion must diffuse outwards faster than the chromium ion, but, as already noted by Preece and Lucas, the immediate formation of a layer of chromium oxide on alloys with 25 per cent or more of chromium suppresses the oxidation of cobalt, thereby preventing the formation of spinel. The exclusive formation of a layer of chromium oxide is responsible for the excellent resistance to scaling of iron-base and nickel-base alloys containing 25 per cent of chromium. In fact, the rate of scaling at this critical concentration of chromium seems to be independent of the base metal, whether it be iron, nickel or cobalt.

In spite of the very great decrease in rate of scaling produced by 25 per cent of chromium in continuous oxidation runs, its poor resistance to spalling would seem to preclude its use for components undergoing cyclic changes of temperature. The scale formed on alloys with more than 20 per cent of chromium spalled badly on cooling to room temperature. This property must seriously reduce their value unless the spalling resistance can be improved, as in the case of nickel-chromium alloys, by the addition of small amounts of another element such as silicon.

Metallurgical Reviews

THE Institute of Metals has started the publication of a new quarterly periodical, *Metallurgical Reviews**. It will contain reviews of progress in various fields of interest to metallurgists and will deal with both theoretical and industrial topics. The first number contains four papers : "Metallurgical Aspects of Microradiography," "Mechanical Properties in Relation to Design Requirements," "The Principles of Continuous Casting of Metals," "The Preparation and Properties of High-Purity Iron." The second of these, by Professor C. R. Soderberg, Dean of the Massachusetts Institute of Technology School of Engineering, traces the changing attitude to the problem of testing materials throughout the years, surveys the more fundamental approach which has led to a better understanding of the mechanism of failure, and throws light on the tests most suitably to be applied in the selection of materials for specific purposes. The review of the principles underlying the continuous casting process, contained in the third paper, and the assessment of the factors operating in the process which now occupies an important place in metallurgical industry, will lead to a better understanding of its possible application.

This publication will clearly be of interest to metallurgists and, as the subjects of articles projected or in course of being written include, under the general heading Metallurgical Engineering, items such as wire drawing machinery, rolling mills, and extrusion presses, it promises to be of direct value to engineers connected with metallurgical industry.

* *Metallurgical Reviews*. Published quarterly by The Institute of Metals, 17, Belgrave Square, London, S.W.1. Annual subscription, for members of the Institute of Metals, 32s. 6d., or non-members, 42s. 6d.

Hardening of Austenitic Stainless Steel

HARDENING by precipitation of carbide is possible in chromium-nickel austenitic stainless steels. In 21 : 12 chromium-nickel steel containing 0·5 per cent of carbon, a Vickers diamond hardness of nearly 400 can be obtained by solution and ageing treatment, and in the presence of high phosphorus this can be raised to 480.* Such a composition, has disadvantages compared with low-carbon steels of rather lower nickel and chromium content. In the low-carbon steels, however, the carbide does not separate as a fine dispersion, but as a film in the grain boundaries giving little increase in hardness, but rendering the steel susceptible to intergranular attack. Additions, for example, of aluminium are therefore made to low-carbon varieties of austenitic stainless steels to provide a more suitable form and composition of the precipitated particles.

Armco 17–7 PH is a precipitation hardening steel containing carbon 0·07, chromium 17, nickel 7 and aluminium 1·2 per cent. An article by M. W. Marshall, D. C. Perry and N. R. Harpster† describes how enhanced properties can be obtained in this steel by a modification of the usual precipitation hardening treatment. In the soft condition the steel has a microstructure of austenite with 5 to 20 per cent of delta ferrite. It has excellent forming properties and can be hardened by cold work followed by heating at a temperature between 370 deg. and 590 deg. Cent., a treatment which causes the deposition of an aluminium-rich precipitate and also acts as a stress reliever. The austenite is unstable, but if the steel is cooled from 1065 deg. Cent. the austenite to martensite transformation does not start until the temperature is well below −75 deg. Cent. If the steel is reheated and cooled from 760 deg. Cent. the transformation starts at about +75 deg. Cent. and sufficient martensite is obtained at room temperature to give, in the material subsequently heated at 565 deg. Cent. (1050 deg. Fah.), a tensile strength of at least 80 tons per square inch. This is referred to as the TH 1050 treatment. Still higher tensile strength can be obtained by using an austenite conditioning temperature which depresses the martensite transformation to a lower temperature, and inducing the change to start by an intermediate refrigeration. A stronger and harder martensite is thus obtained and on precipitation hardening at 510 deg. Cent. (950 deg. Fah.) higher strengths can be developed than are obtainable by the TH 1050 treatment. The recommended procedure (RH 950 treatment), starting with material solution annealed for one minute at 1065 deg. Cent., is : heat at 950 deg. Cent. for ten minutes and cool in air (martensite transformation starts at +10 deg. Cent.); cool to −75 deg. Cent. and hold for eight hours ; heat at 510 deg. Cent. for one hour and cool in air. Curves are given in the paper indicating the effect of austenite conditioning temperature and time, refrigerating temperature and time and final hardening temperature and time. In passing from the annealed condition to RH 950, there is an overall expansion of from 0·004in to 0·005in per inch in all directions. Average properties of Armco 17–7 PH steel after these treatments are given as :

	Annealed	TH 1050	RH 950
0·2 per cent yield strength, tons per square inch	21·2	79·4	96·7
Tensile strength, tons per square inch...	57·6	86·2	102·8
Elongation, per cent on 2in ...	38·6	9·4	7·2
Rockwell hardness	B 85	C 42	C 46
Equivalent Vickers diamond hardness...	163	420	440

On the basis of results of short-time tensile and yield strength tests over the range −75 deg. to 540 deg. Cent., in which its strength was well maintained, it was concluded that 17–7 PH, in the condition RH 950, should be considered along with the strongest sheet materials currently available for service at temperatures up to 325 deg. or even 425 deg. Cent.

* *Trans. Amer. Soc. for Metals*, 1954, Vol. 46

† *Metal Progress*, July, 1956, page 94.

LETTERS AND LITERATURE

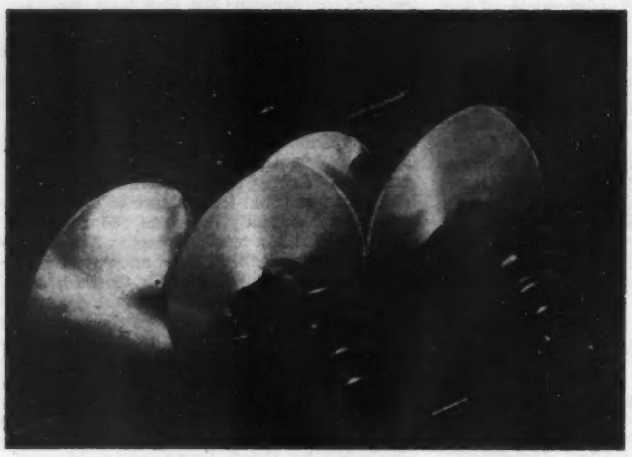
Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

ONE-TOOTH PINIONS

SIR,—I was very interested to read the letter from Mr. F. E. Lindsay on this subject. So far as I know, Mr. Lindsay's claim to have originated the idea of meshing involutes together in this way is the only one. I first heard of the possibility of doing it from Dr. H. E. Merritt about twenty-five years ago, and so far as I can recollect he himself had learned of it from some published work.

I had long had a desire to see the principle embodied in metal, but only recently had the opportunity of making a pair of such gears. About a year ago the task was undertaken in the department of applied mechanics in the University of Sheffield, partly as an exercise in improvisation and partly for its academic interest. A photograph of the gears mounted for rotation by an electric motor is reproduced on this page.



One-tooth pinions constructed at Sheffield University

It is impracticable to secure continuity of action for a complete revolution in spur gears of this character. The obvious way out of this difficulty is to use staggered spur gears, and the natural development from this idea is to use helical teeth. The gears shown are aluminium castings with the profiles generated by a single-point cutter used in a universal milling machine. The pattern for the castings was a staggered spur gear with about forty steel laminations filed to a template, set in correct angular relation and smoothed off by a filler-paint in the steps.

The main dimensions (in) are :

Base radius	1·146
Lead	7·200
Tip radius	4·470
Centre distance	5·500
Face width	4·900

The lead of the helices and the face width were adjusted to give continuity of tooth action, but the face width is not great enough to give a constant total length of line of contact in all phases of engagement. The gears rotate in a common direction quite smoothly at about 200 r.p.m. They have not as yet been subjected to load.

W. A. TUPLIN,
Professor of Applied Mechanics
Sheffield University,
September 14th.

OUR ROADS ARE PERILOUS

SIR,—I should like to offer my congratulations on the excellent leading article entitled " Our Roads are Perilous " in your issue for September 14th. The particular aspect which you stress, that the ordinary road user is expected to make correctly as many snap judgments in a single day as a ship's captain, an aircraft pilot, or a train driver, will be called upon to make in a lifetime, is an aspect of our personal transport system which I think should be brought home to everyone, particularly those in authority. The sentimental and emotional appeals to road users is entirely useless if the technical standards of performance on the roads are beyond the normal human being's ability. As an engineer and motorist for nearly 30 years, this aspect of technical ability is one which has impressed me, but which does not appear to impress the authorities, who seem singularly lacking in getting down to a real solution to our problem. I might add one other opinion, which is that the addition of more and more rules and regulations which the average road user must bear in mind, plus the increasing multiplicity of road signs upon which he must act in many cases in a matter of seconds, are making the position progressively worse in that they call for an ever-rising standard of performance.

K. J. WILKINSON,
Deputy Managing Director
The Spiral Tube and Components
Company, Ltd.,
Derby, September 14th.

CALCULATION OF BACKLASH BETWEEN GEAR-TEETH

SIR,—To the problem discussed by Professor Tuplin in your issue of August 10th, there is a quicker and more accurate solution. It is as follows.

Let two gears having tooth-numbers t and T, addendum coefficients k_p and k_w, helix angles σ_p and σ_w (for helical gears) be cut full depth and meshed at a centre distance which exceeds the nominal value by $e=(k_p+k_w)/P$. (For helical gears substitute P_n for P.) The true backlash z_0 (normal to the tooth surfaces) may be found as follows :

(*a*) For spur gears:

(i) Find the nominal centre distance $C=(t+T)/2P$.
(ii) Find the extension $e=(k_p+k_w)/P$.
(iii) Find a factor $K=C/e$.
(iv) Find the multiplier Ω corresponding to $1/K$ from a curve.
(v) Find the true backlash from $z_0=e\Omega/K$.

The multiplier Ω may be calculated, in general, from

$$\Omega=2[K^2\cos\psi_g(\text{inv}\,\psi_e-\text{inv}\,\psi_g)-K\sin\psi_g]$$

where ψ_g is the pressure angle of generation, ψ_e the pressure angle of engagement, and $\sec\psi_e=\sec\psi_g(K+1)/K$. Co-ordinates for a curve connecting Ω and $1/K$, for $\psi_g=20$ deg., are as follows :

$1/K$	0·01	0·02	0·03	0·04	0·05
Ω	2·495	2·42	2·35	2·285	2·225
$1/K$	0·06	0·07	0·08	0·09	0·10
Ω	2·17	2·12	2·07	2·03	1·985

The same curve can be used for helical gears with a normal pressure angle of generation of 20 deg.

(*b*) For helical gears (at shaft angle $\Sigma=\sigma_p+\sigma_w$) :

(i) Find the virtual nominal centre distance $C_v=(t\,.\sec^3\sigma_p+T\,.\sec^3\sigma_w)/2P_n$.
(ii) Find $e=(k_p+k_w)/P_n$.
(iii) Find $K=C_v/e$.
(iv) Find $z_0=e\Omega/K$ as before.

In Professor Tuplin's example, the exact value of z_0 is 0·177 and the approximate value 0·165.

From the data, $t=T=4$, $k_p=k_w=0{\cdot}5$, $\sigma_p=\sigma_w=45$ deg., $P_n=1$.

Then

(i) $C_v=(4\sec^3 45\text{ deg.}+4\sec^3 45\text{ deg.})/2\times1=11{\cdot}3$.
(ii) $e=1$.
(iii) $K=11{\cdot}3\div1=11{\cdot}3$; $1/K=0{\cdot}0885$.
(iv) Ω from curve$=2{\cdot}03$.
(v) $z_0=1\times2{\cdot}03\div11{\cdot}3=0{\cdot}180$.

All by slide rule.

H. E. MERRITT
Warwick, September 12th.

Literature

Effective Supervision. By MILON BROWN. The Macmillan Company, New York ; 10, South Audley Street, London, W.1. Price 31s. 6d.

AFTER carefully reading this interesting book the impression is formed that efficient supervision might almost be defined as organised common sense, for technical knowledge, though admittedly essential, will form but a very little part in the life of a supervisor. The official the author has primarily in mind is one recently promoted from the rank and file, but the principles enunciated hold good throughout an organisation and even the seasoned manager would probably profit by some of the suggestions made. The author advocates the close study of the methods adopted by successful colleagues, for he himself has evidently done this with the result that he is able to set others on a course that he has proved to lead to increased efficiency, but he rightly cautions the reader

that a perusal of the book will not suffice; the principles in it must be put into practice.

In the first chapter what is involved in the job of supervision is clearly set out, with particulars as to the qualities that go to make a good leader, among which those of self-restraint and of sound judgment are given a high place. If employees work *with* their supervisor "they will not fail" him. The next chapter is devoted to establishing good relationships both up and down the industrial ladder. We proceed in Chapter 3 to an examination of what is expected of a supervisor; it is most important for him to realise from the start that it is not right for him to do the work of employees, he must rather "see that they can do it and can do it well," and for this, as one in authority, he must have a clear conception of actual requirements. Chapter 4 looks into the resources that are available and how they can be utilised. The author pays much attention to the selection of suitable workpeople (Chapter 5), but too often this is left to a special personnel department, whereas we feel it is essential that a supervisor should have the opportunity of being present at all interviews of prospective candidates, for he can do much by the way in which a man is introduced to his work, and by his being set at rest in his new job, letting him know exactly what is expected of him. In Chapter 6 the supervisor is reminded that he will always have to keep an eye on those entrusted to his charge with a view to determining their value to the organisation and their fitness for better work. The suggestion is made that he should jot down what he specially notices, but not in the presence of a worker. Chapter 7 deals with the important subject of training and contains a number of useful suggestions, but while in themselves they are excellent we cannot help wondering if any supervisor will have the time to do all Mr. Brown recommends. Chapter 8 is entitled "Motivating Your Employees," and is occupied with ways to improve the morale of both individuals and groups so that the work will remain at a high level, perhaps only attained by instilling in a team the real desire to work; this should begin as soon as an employee is started by letting him realise that there is a friendly atmosphere in the workshop and that working conditions are good. If really good relations are established the labour turnover will be low. The author truly says that "there is no simple rule or magic formula that will enable you to establish desirable relations with your employees" The part played by the supervisor in the labour contract is investigated in Chapter 9, and here the matter is explored from the American standpoint, the industrial laws cited being those passed in the U.S.A. Nevertheless, the principles enunciated are applicable in this country, where we should be glad wholeheartedly to endorse the opinion that nowadays "labour and management find that they can settle their differences to better advantage at the bargaining table than through strikes and lock-outs." The responsibility of a supervisor doing all in his power to assist in the control of costs is stressed in Chapter 10, and here we might point out that this is only possible when costs are broken down by the cost accountant in such a way that a separate statement of shop costs is available in reasonable time. The question of safety is discussed in Chapter 11, and here the supervisor can do much to help prevent accidents, particularly by not ignoring one because no apparent harm has been done, for probably the next time a similar case occurs injury will result; indeed, he should always be alert to eliminate hazards, while ensuring that all accidents, however trivial, are duly reported. The last chapter (12) is valuable as giving hints to a supervisor as to what his future opportunities are likely to be, at the same time warning him that while ambition is a desirable attribute, expecting too much in too short a time may lead to a feeling of frustration. Should the newly appointed supervisor think that this book expects too much he need not be discouraged, for experience comes gradually and this work will help him to acquire that experience in a systematic manner.

We are of the opinion that the author might have paid some attention to the pitfalls likely to be encountered in an organisation where functional administration is applied, where too often the supervisor on the shop floor feels—unjustifiably, even though naturally—that his authority is being undermined.

A helpful feature of this book is to be found in the brief conclusion at the end of each chapter, followed by a set of questions which are, generally speaking, arresting in character. Some of the terms and expressions used may seem strange to British readers, who would be surprised that they "might be clawed out" or that they had "dead lines to meet," while they gave "answers off the cuff," and knew well "how the grape vine works," but were prepared to give consideration "when a man has a gripe." "Backlog," "job know-how," "application blank" explain themselves. All those engaged in supervision in any form will find much to interest and help them in the book before us.

Engineering Fluid Mechanics. By Charles JAEGER. Translated from the German by P. O. Wolf. Blackie and Son, Ltd., 16/18, William IV Street, London, W.C.2. Price 60s.

THE author of this book, until ten years ago, was a professor at the Swiss Federal Institute of Technology, Zurich. He then came to this country where he is now a practising engineer, as well as special lecturer in the post-graduate course in hydro-power engineering at the Imperial College, London. His career furnishes one possible explanation why his book provides, in addition to a wealth of scientific and practical information, much food for thought on matters of broader import: matters which have been discussed in these columns on several occasions and, indeed, have been debated in the serious lay Press.*

At a time when the expansion of technological training has become recognised as being of fundamental importance to this country, this book is welcome as making a useful contribution in this direction. This country has long benefited from its wealth of engineers in whom flourished the "art of directing the great sources of power in Nature for the use and convenience of man." The need to-day is for men who can translate the ideas of science into the realities of engineering, and who will improve the valuable intuitive technique of the experienced engineer by the application of rigorous scientific method and knowledge. As Dr. Jaeger states in his first preface, his book is intended to present to the reader the methods of analysis and calculation, based on rigorous mathematics and physics, which are required for the design of water-power schemes. He welcomes the empirical knowledge which had been built into the body of hydraulics of old, but gives it more general significance by the application of the laws of fluid mechanics and of mechanical similarity.

The first part of the book covers, briefly, the physical basis of hydraulics, and touches on the theory of dimensionless parameters and of similarity. It then discusses turbulent flow in pipes and open channels, and mentions the fundamental work of Prandtl, von Kármán and Nikuradse in Germany, and of White and Colebrook in Great Britain—a subject worthy of study by those bewildered by the profusion of experimental flow formulæ.

The second part, devoted to steady flow, discusses the basic hydrodynamic equations, the energy approach leading to Bernoulli's theorem, the force and momentum approach, the general theory of critical depth, and the stability of flow in open channels. Much attention is given to flow in open channels, which is "gradually varied" (back-water, draw-down) and "rapidly varied" (hydraulic jump, expansions and contractions).

The third part, on unsteady flow, deals thoroughly with mass oscillations in surge tank installations of various kinds, and with water hammer, including hydraulic and mechanical stability and governing; also, less extensively, with surges in open channels. Both analytical and graphical methods of computation are fully described. A section on the design of underground power stations is an interesting application of the theory presented in this part of the book.

The fourth part provides a useful introduction to seepage and ground-water flow. It is followed by three appendices, which are, in fact, miscellaneous chapters, on empirical flow coefficients, on the theory of flow over an erodible bed, and on density currents.

The book clearly covers ground which is largely common to those civil and mechanical engineers who are concerned with the control and utilisation of our water resources, and should be of great interest to practising engineers.

It is, however, even more notable as an educational work, as briefly mentioned above. With all necessary reservations about the great progress of civilisation since the eighteenth century, Dr. Jaeger appears to be a spiritual descendant of his great fellow-countrymen, Leonhard Euler and the three Bernoullis. Two centuries ago great scientists would be capable also of mastering the fields of theology, philosophy, languages and medicine, whereas to-day's innovator is more restricted in his scope. Even so, it is remarkable to see how the author has made important original contributions in various branches of the mechanics of fluids (most of them incorporated in the book) as well as in the theory of structures and in the mechanical-engineering fields of hydraulic and mechanical stability. He refuses to follow the ever narrower and deeper groove of specialisation, and allows his mind to range; is it possible that great progress arises out of the synthesis of several branches of learning which, before, had been treated as separate and unconnected?

The sources incorporated, in some part, in the book include British and American, German, French, Italian, Spanish and Portuguese works and are quoted in numerous footnotes ensuring a breadth of view in this respect also.

Dr. Jaeger's work provides a good example of the organic, historical approach advocated by those of us who consider a scientific and engineering curriculum to be as broad and "educative" as the classical education in the arts: the text stresses past developments and the direction of current progress, and is reinforced by some biographical footnotes.

* See, for example, the recent correspondence in *The Times* on the history and philosophy of science.

Urban Motor Roads

No. I

The British Road Federation held a conference on urban motorways on September 18th–20th last, at the Friend's House, Euston Road, London. The principal papers were listed briefly in a note last week. Here we give a brief résumé of the work of the conference, and abstracts from some of the papers.

THE handling of road traffic in cities and towns is the core of the modern traffic problem. Congestion and accidents are rife in all the large towns of Britain, and conditions are little different in the towns of most other countries, although London, on account of its size and its lack of modern traffic routes, is probably the most acute case amongst European cities. The British Road Federation's conference drew attention to these problems, and the views of many persons—such as planners, economists and town councillors, as well as engineers—were ventilated during the three days the conference was in session at the Friend's House. Here we give only a brief résumé of some of the principal papers before the conference, followed by some of the outstanding points from the various discussions. However, the conference is also discussed in a leading article on page 425

The first paper before the meeting was written jointly by Dr. Glanville, director of the Road Research Laboratory, and Mr. J. F. A. Baker, chief engineer (highways) of the Ministry of Transport and Civil Aviation. It was entitled "Urban Motorways in Great Britain?" and its authors pointed out that it sought to answer objectively the question why we in this country should necessarily follow the lead of others in constructing urban motor roads, and whether there was any effective alternative. An analysis of the costs and benefits was thus made of two specific examples, and the associated problems of parking and the use of a motorway for public transport were examined. From the closely-reasoned arguments of the paper we reproduce an abstract in the next paragraphs.

Fly-over roundabout in Rotterdam. The through route leads to a tunnel under the river. The city's motorway system was started before the war, and at present motorways are planned along three sides of the city

In Great Britain 80 per cent of the population live in towns and about half of the total vehicle-mileage on roads is travelled in built-up areas. Because of the great concentration of activity in towns and the preponderance of road travel over other forms of transport, congested roads and slow journeys have come to be the rule in such places. It is not surprising that in these conditions highly populated areas are accompanied by numerous accidents. National statistics show that 75 per cent of all road casualties in this country, and 90 per cent of those sustained by pedestrians, occur in built-up areas. Moreover, the network of roads in towns is so complex and junctions so frequent that half the casualties in built-up areas occur at junctions.

The largest single movement in London is probably the daily journey to and from the outer suburbs to the central area. In 1949 about three-quarters of a million persons arrived daily in this area (Holborn, Finsbury and the Cities of London and Westminster) by all methods of transport, excluding those whose journeys were not connected with work or school; 93 per cent of them used public transport.

Since 1949 there has been a reduction in the use of public transport in London each year. On the other hand, as will be shown later, the use of private cars has been increasing.

Censuses made by the police, usually every two years, show many of the main features of traffic composition and growth in the area. Thus, there has been two and a half times as much growth in the outskirts as at the centre, where conditions are too congested for large increase to be expected and many roads and intersections are working near to capacity. The average flows on main roads in Central London between 9.30 a.m. and 5 p.m. on weekdays have been obtained in the course of six surveys made by the Road Research Laboratory.

The most noticeable features here are the rapid increase in private cars since petrol was derationed in 1950, the steady rise in commercial traffic throughout the whole period, and the slow decline of buses and taxis.

The number of vehicles present in Central London has been calculated from counts made at a number of sites in June, 1954. There were about 45,000 vehicles an hour (total both ways) crossing a cordon roughly 1 mile in radius centred on Aldwych between 9.30 a.m. and 5 p.m. on weekdays. An area of 8½ square miles of Central London contained some 8500 moving vehicles at any instant between these hours, about thirty per mile of road. It is interesting to note that private cars formed 37 per cent of total traffic, but carried 18 per cent of all occupants (including drivers), whereas buses carried more than half of all vehicle occupants, yet formed only 7 per cent of the total traffic. Commercial vehicles (35 per cent of all traffic) carried 14 per cent of occupants, and taxis (20 per cent of the traffic) carried 12 per cent of occupants.

The average speed of moving vehicles on main roads in Central London between 9.30 a.m. and 5 p.m. was 16 m.p.h. in 1954. Journey speed, i.e. the speed based on total journey time including all stops and delays, was about 11 m.p.h. The difference of 5 m.p.h. between this and running speed is caused by stops at controlled intersections, about one-third of the total journey time being accounted for in this way.

On some roads, e.g. parts of Oxford Street, journey speeds were as low a 5 m.p.h. On others average speeds up to 24 m.p.h. were regularly maintained, especially where roads were wide and the proportion of commercial traffic was low.

In the survey made in 1954 the longest average stopped time of 104 seconds occurred in City Road—St. John Street ("The Angel"). Stops at the Bank, Oxford Circus and Ludgate Circus were on the average between sixty and eighty seconds. There was much variation in stopped times, but individual stops of more than two minutes were comparatively rare; at 20 per cent of the 175 controlled intersections on the roads studied the mean stopped time exceeded thirty seconds. Thus, the number of controlled points encountered per mile of route, as well as the mean time spent stopped at each, has an important effect on reducing journey speeds. Along Oxford Street, one of London's most congested shopping streets, the mean stopped time at each signal was only about twenty-five seconds, but as there were thirteen signals along the street an average of 5½ minutes was lost at them out of a total journey time of about 11½ minutes.

Attempts have been made to estimate the amount of the delay experienced by vehicles on Central London roads. At forty-two traffic signals, for instance, it was estimated that on weekdays between 8 a.m. and 8 p.m. about 17,000 vehicle-hours were lost due to stops or delays caused by slowing down or accelerating. Slightly less than half this loss took place at the ten worst intersections.

What Will Happen If We Do Not Have Urban Motorways?

The picture that has been painted of traffic conditions in Central London can be found in varying degrees in the centre of all our towns, both large and small. Furthermore, the position is not static. Between 1954 and 1955 there was an increase of over 11 per cent in vehicle registrations. Since 1950, estimates of growth of motor traffic indicate that in the country as a whole the total mileage travelled by all motor vehicles taken together has been increasing at about 8 per cent per annum. At simple interest this would mean a doubling of traffic in 12½ years. In Central London on the main routes the increase has been about half the above percentage. These figures show the rapidity with which the problem is growing and the need for grappling with it as an urgent matter.

If motorways are not constructed in our towns, the principal measures remaining by which to tackle the traffic problem are local improvements, such as widening existing roads and traffic restriction and regulation to control its volume or ease the flow. The possibilities of these measures will now be examined.

There are many places, particularly intersections, where appreciable relief to traffic can be provided by relatively minor measures. One example of this is the intersection of High Holborn with Kingsway in London, where widening the carriageway on the western approach by 3ft at low cost gave an increase of 15 per cent of capacity on that approach.

Moreover, it is estimated that the improvement was paid for in two years by the benefits to traffic. However, measures of this kind are of limited application and are extremely expensive in some of the worst cases. The cost and possible benefits from some of these more expensive widenings can be exemplified by certain schemes proposed in the 1951 Development Plan of the London County Council.

In September, 1954, the Road Research Laboratory made a survey of traffic conditions on some 36 miles of main road in Inner London. The survey provided estimates of delay at intersections, many of which are scheduled for improvement under the L.C.C. Development Plan at a cost of £31 million (1951 values). If all the delay at the intersections due for improvement on the roads surveyed were eliminated, journey speeds would increase from 10·8 m.p.h. to 12·5 m.p.h. As delays will not be entirely eliminated, the actual improvement in journey speed will be less than this. At a time when the number of vehicles is growing, this cannot be regarded as going far towards solving the traffic problem.

It is not suggested that this situation was of the London County Council's choosing; the London County Council are, of course, equally aware of the limited results likely to be derived from the programme in question.

Restriction and regulation have been the most common methods of attempting to relieve traffic congestion since the war. These have included prohibition of turns, making streets one-way and prohibition of parking.

Right turns can impede the free movement of traffic, and it has been found that the removal of each 1 per cent of right turning traffic increases the capacity of a signal controlled intersection by at least ½ per cent.

One-way streets speed up traffic, make signal control simpler and reduce accidents, but one-way systems can sometimes lead to an overall increase in journey time because the diverted traffic has to travel a greater distance.

Restrictions on waiting have led to higher speeds in Central London and Glasgow, changes of 10 to 15 per cent being observed. Unilateral waiting has also proved beneficial in a number of cases.

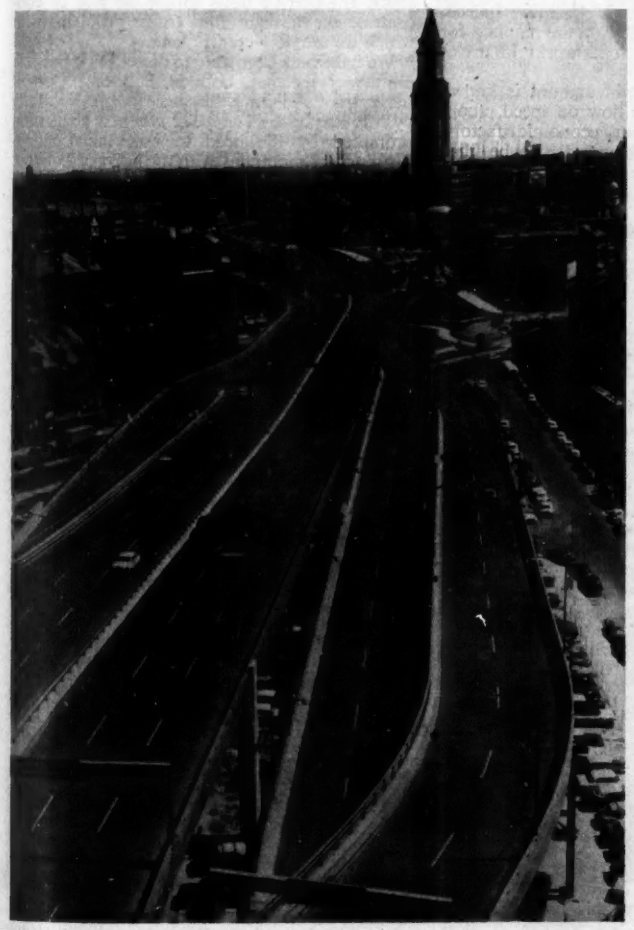
It is felt that more could be done in regard to the prohibition of parking or the stopping of vehicles on important routes in built-up areas and also the positive sign-posting of nearby streets in which parking is permissible. But such measures cannot always be completely beneficial, because, in providing relief for through traffic, they may sometimes cause inconvenience and expense in other ways.

It is sometimes suggested that a solution to traffic problems is to be found by restricting entry by car into the centres of towns, so that most people would either have to use public transport, walk, cycle, or not travel at all. This drastic suggestion, which would restrict the individual's choice of transport and which might be expected to lead to a reduction in trade in the central areas, is no real solution to the problem and seems unlikely to have public support. In London, as we have seen, bus traffic has been declining in the past few years, which suggests that people are not satisfied with public transport at present, whereas car traffic has been increasing, presumably because drivers are finding it more convenient, more comfortable and perhaps cheaper (where a car is supplied to an individual by his employer—much cheaper) to use a car than to travel by public transport. There would also be a number of practical difficulties in carrying out the proposal. Thus, in London in 1947, when no petrol was available for private motoring, over a quarter of the traffic on main streets in the central area was car traffic; presumably these cars were in use for business purposes and would still claim special privilege. This would mean a system of permits and controls of considerable complexity.

A further alternative would appear to be to develop the public transport system, especially in the very large towns. A cheap, convenient and rapid form of public transport could do a great deal to relieve the congestion in urban centres. In London the benefits derived from the Tube system are enormous, and an extension of this system with a reduction in buses on the surface could bring appreciable benefits in some areas. However, the cost of building Tubes is high; estimates in the B.T.C. Bill, 1954–55, indicated a cost of £3,000,000 to £4,000,000 per mile.

Although attempts to stagger working hours have, in the past, met with little success, it must be admitted that the cost of public transport could be reduced if the peak load could be spread. Further attempts to obtain a better stagger of working hours should therefore be made; but it is not clear that the public is convinced of the benefits to be obtained from staggered hours.

It is thus apparent that any attempt to relieve congestion in our towns either by localised improvements or by a proliferation of restrictions on traffic can only be a limited solution, and in some cases the latter could lead to an overall reduction in potential movement and to the decline of business in the central areas of towns. For instance, studies in the U.S.A. have revealed a relative decline in the importance of retailing as a business activity and in land values in the central area of towns compared with the suburbs, and this decline is attributed in part at least to traffic congestion and difficulty in parking. We are driven to the conclusion that a comprehensive solution to the problem must include new roads and, as will be seen, there is evidence to show that greatest benefits are likely to come from



Entrance and exit ramps on elevated expressway at Boston, U.S.A. Many design and constructional difficulties were experienced here; the expressway ramps can be steam heated to melt snow

Harbor Freeway, Los Angeles, U.S.A., showing its relationship to the central business district. The free-way system is considered in Los Angeles to have proved its worth, the most serious criticism being that not enough of it has been built

building such new roads as urban motorways.

Urban Motorways as a Solution

Motorways, being special-purpose roads and free from intersections on the level, provide high traffic capacity. Normann gives the capacity of an urban motorway as 1500 vehicles per hour per lane at average speeds of 30 m.p.h. to 35 m.p.h. In Los Angeles, Forbes has reported flows on some lanes of a six-lane divided freeway of nearly 2000 vehicles per hour per lane at average speeds of about 45 m.p.h. Main streets in Central London with an average width of 40ft and carrying two-way traffic are only passing about 1500 vehicles per hour at an average speed of only 11 m.p.h. If these were replaced by a motorway with two lanes in each direction, 6000 vehicles per hour or more could be carried at an average speed in excess of 30 m.p.h. A motorway is clearly a much more efficient way of using space for moving vehicles where land is scarce and land costs are high, and there is thus a very material benefit to be gained by constructing traffic channels as motorways. The junctions required to enable traffic to get on or off the motorway will take space, but this is not in general a large proportion of the total space required.

Accident rates on urban motorways are much lower than on ordinary town roads. The table makes some comparisons.

Accident Rates

	Personal-injury accidents/10^8 vehicle-miles	Fatalities, 10^8 vehicle-miles
Roads in the London area :		
Main streets in Central London...	8	3
Great West Road, A.4	6·9	38
Uxbridge Road, A.4020	7·1	43
Urban motorways in the U.S.A. :		
Metropolitan New York systems*	—	2·5
Hollywood Freeway	—	1·8
Texas, Houston Gulf Freeway (City)	—	1·6
Arroyo Seco Parkway...	0·7	2·0
Riverside Drive	0·4 to 1·1	—

* From this and other information Barnett concluded that "... full control of access (as by motorways) results in an accident and mortality reduction of ½ to ¾."

The figures for total injury accident rates on other limited access highways which do not necessarily pass through urban areas are similar. It can be taken as proved, therefore, that motorways can bring substantial savings in total accidents.

Not only is the overall accident rate lower on motorways but the number of deaths per vehicle-mile is also less. The results show that, whereas the difference between fatality rates on the congested roads in Central London and on the American motorways is perhaps not very great, the fatality rate on the motorways is very much lower than on traffic routes as they exist around London to-day, such as the Great West Road, which carry fast traffic through areas of mixed urban development.

The benefits to the motorist of relatively safe, free-flowing travel on urban motorways compared with that on the ordinary town streets have been estimated for roads in Los Angeles as follows :

	Average saving per vehicle-mile (cents)
Savings in petrol	0·33
Savings in maintenance	0·24
Savings in accidents	0·56
Savings in time (commercial vehicles only)	0·87
Total	2·00

Using these results it was estimated that the savings on about 17 miles of urban motorway, which cost 42,000,000 dollars, was about 12 per cent per annum, and this was considered to be an underestimate of the true benefits. Experience in Los Angeles further indicates that the removal of through traffic from existing streets to urban motorways benefits business property values, increases speed and improves safety on existing streets.

It thus appears that the benefits obtained by constructing motorways in towns are considerable. However, to be fully effective they should be planned in relation to the overall needs of transport in the area, particularly of public transport, and they must, of course, be provided with proper terminal facilities and accesses to the existing streets. It is to be noted that in the U.S.A. fast public rail transport is sometimes being provided in the central reservation of urban motorways, e.g. Congress Street Expressway in Chicago.

Planning Motorways in British Towns

The evidence given so far shows that there is a strong case for considering in detail the extent to which urban motorways can help to relieve our congested traffic arteries. This raises the questions : "How should motorways be planned ?" and "Have plans been prepared for motorways in any of our towns ?"

Motorways should be considered in relation to the general plan for traffic. This requires a survey of traffic conditions on existing streets and a survey of the origins and destinations of the journeys which people make. Using the information provided by these surveys, it is possible to select the most satisfactory location of main traffic routes, to estimate the amounts of traffic likely to use them and to estimate the relief to the existing street system. The estimates so made then form the basis for the design of motorways and for calculations of the economic benefits and savings in accidents likely to accrue to the community from building them.

Techniques for making surveys are available, and it is not proposed to discuss them here except to mention what is perhaps the most extensively used method in the U.S.A. for urban areas, namely, the method of interviewing people in their homes and offices about the journeys they make. The method has been used on a very small scale in London. The cost of such surveys is a minute fraction of the cost of the works, and the information obtained is fundamental to a proper design.

Although surveys have been made to estimate the amount of by-passable traffic in a number of places and a certain amount of census information has been obtained, so far as the authors are aware, no comprehensive traffic surveys have been made in towns in Britain. Indeed, much more complete traffic data are required for the rational planning of road works in urban areas in this country.

Again, although a certain amount is known about the effect of traffic flow on speed, about accident rates and about economic factors, there are many gaps in knowledge to be filled before anything but rough estimates can be made of the full benefits likely to accrue from urban motorways.

[Here examples of possible motor roads in London are given—the proposed "A" ring, and a connection between the "A" ring and the London-Birmingham motorway at Aldenham.]

It appears that a proportion of the potential of a motorway will always be developed without additional parking and unloading facilities, but that the full potential, so far as stopping traffic is concerned, can only be developed if these facilities exist or are provided.

Motorways, by providing a channel for relatively quick-moving traffic, offer opportunities of developing fast public transport services which could be used, e.g. for bringing workers from the residential suburban areas to the business areas in the centre. Because of the high speed on the motorway frequent services could probably be maintained with a relatively small fleet. Fast transport of this kind might attract the patronage of some persons who now use their private cars to travel to and from work as well as relieving the strain on local railway services.

It is of interest to examine this in a little more detail. An eight-car tube train operating at the maximum frequency of thirty-five per hour in one direction will take a maximum of 42,000 passengers per hour. This number of people could be carried in 1000 buses or coaches carrying forty-two per vehicle. Travelling at 40 m.p.h., this would mean one bus every 70 yards occupying a single lane. There may be reasons why this frequency could not in practice be achieved, but this use of, say, a single lane allocated for the purpose at peak hours would seem to offer advantages well worth examining carefully. The buses themselves could, of course, be routed so as to pick up passengers within a reasonable operating distance from the motorway, the motorway forming the express route. At the town terminus either special unloading facilities could be provided and linked to other means of distribution or the buses themselves could be routed so as to do their own distribution.

We started out by posing a number of questions and have now reached the point where we should consider to what extent these have been answered.

Taking London as our primary example, we have seen that the existing network of traffic routes is inadequate for the present traffic, that there is a limit to the extent to which flow can be improved by regulation and restriction, and that one of the major problems is delay at junctions and intersections. It has been shown that very heavy expenditure on the improvement of existing roads and intersections can only to a very limited extent ease traffic flow.

On the other hand, the benefits to be obtained by constructing motorways in towns are considerable. There will be immediate benefits even though the motorway is, at the beginning, only a part of a larger system. The benefits will increase as the full system is developed and the facilities for parking and for loading and unloading are also provided.

Speed of construction is vital because modern traffic trends make it quite unrealistic to expect a relatively slow-moving programme, even if it includes motorways, to do anything but lag far behind the mounting traffic problem.

Motorways should be based on the general plan for traffic of all kinds. So far as road traffic is concerned, this should be based on careful surveys of traffic on existing streets and of surveys of origins and destinations. To provide this information there is a need for strong traffic engineering units in both central and local highway engineering departments. Since there is a shortage of junior engineers trained in this branch of engineering, there is a need to provide facilities for instructing them. Moreover, the traffic engineering units should be free to concentrate on the enormous traffic problems with which we are now confronted.

We have only been able to discuss two possible motorway schemes, both in London. One of these, the "A" ring, has been considered fully by Mr. Rayfield. The other is a new suggestion prompted by the need to link the London-Birmingham motorway with the heart of London. Although it has only been possible to examine this in a preliminary way, it seems quite a feasible proposition and one which is likely to give substantial economic return on its cost of construction.

Urban Motor Roads in the Netherlands and United States

The papers presented on the second day of the conference by Ing. G. de Bussy (chief engineer of the Rijkwaterstaat) and Mr. A. S. Hodgkiss (assistant general manager of the Triborough Bridge and Tunnel Authority, New York) reviewed experience with urban motorways in the Netherlands and the United States, respectively, the first paper concentrating on the need for the urban routes, and the second on their economic justification. Both of these countries have been active in constructing motorway routes through their largest towns, and the papers show that considerable benefit has been derived as a result. We illustrate the work in these two countries by the three photographs reproduced with this article.

(To be continued)

Refrigerated Vehicles. — We were recently afforded an opportunity by the British Aluminium Company, Ltd., to examine some refrigerated vehicle bodies built by Hawson, Ltd., Brooklands Close, Windmill Road, Sunbury-on-Thames. They demonstrate the advantages of aluminium in this application; in particular the use of stucco-embossed sheet for the outer skin of the body allows it to be left unpainted without appearing unfinished, and, therefore, greatly reduces radiation heat gains. The beams of the body have webs of "Jabroc" densified wood and flanges of light alloy, in order to avoid the conduction of heat to the surface. Refrigeration is by electric equipment, supplied either from an external source or a generator driven by a power take-off on the transmission.

Notes on the Brittle Fracture of Steels

In recent years Sulzer Brothers have made a close study of the problems connected with the brittle fracture of steels. Apart from the current testing of welded structures, special investigations of a more fundamental nature have been carried out. A few of the results received from the firm have been recorded below.

Investigations into the Mechanism of Fracture in the High and Low Ranges of Notch Impact Values

FRACTURES of metals can usually be divided by external observation into the two main classes of ductile and brittle fractures, the former having a dull and almost sinewy appearance with more or less marked reduction in area and the latter normally appearing bright and crystalline with no reduction in area.

In the notch impact test the change from ductile to brittle fracture can be clearly followed in the transition from the high to the low range of notch impact values, so that specimens of this kind are an obvious choice for the investigation of the mechanism of ductile and brittle fractures. The results should help to throw some light on the mechanics of brittle fracture in general.

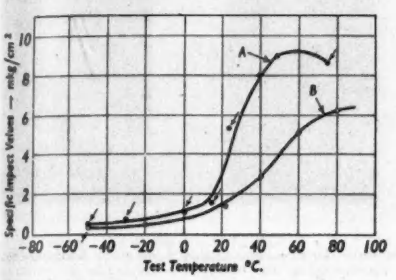


Fig. 1—Abrupt transition in the specific notch impact values of specimens with Schnadt's sharp notch. Steels A (Curve A) and C5 (Curve B)

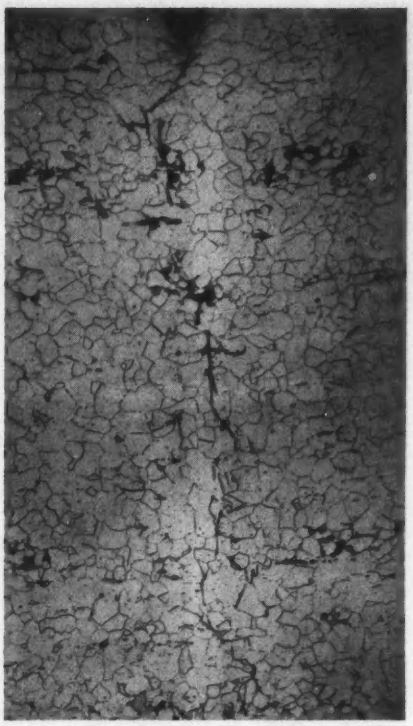
The investigations described in the first part of this article formed part of a comprehensive study of the abrupt transition in the notch impact values of steel.* X-ray diffraction photographs were used to study the deformation of crystals in the surface of fracture of specimens provided with Schnadt's sharp notch, which had been broken in the high and low ranges, and the pictures thus obtained were also compared with with those of specimens subjected to more or less upsetting. An attempt was further made to follow the genesis and development of the fracture in notched specimens by microscopic examination of the neighbourhood of the notch.

The tests were carried out on the steels listed in Table I.

Fig. 1 shows the abrupt transition in the specific notch impact values of specimens with a sharp notch for both kinds of steel. Fig. 2 shows the X-ray diffraction photographs (Co radiation, position of incident X-ray beam at centre of cross section) of the fractured surfaces of specimens of steel A in the high and low ranges. The photographs were taken with stationary and revolving films, the stationary film being on the right and the revolving film on the left. The same figure also shows the X-ray analysis of the base metal in the unfractured state, with the crystals still undisturbed (sharply outlined reflexes in the peripheral and radial directions).

In the high zone ($K_0 \leq 8$mkg/sq cm) the interference points of the (310)-lines in the peripheral and radial directions are very much broadened, a sign that considerable plastic deformation of the crystals has taken place, as revealed also in specimens of steel A subjected to a degree of upsetting exceeding about 20 per cent (Fig. 7*a*). In the low range ($K_0 < 2$mkg/sq cm), on the other hand, the reflexes are much less blurred, especially at the lower notch impact values.

At $K_0 \sim 1$mkg/sq cm the radial broadening of the interferences is so slight that the K doublet can be clearly distinguished. This applies also to the specimens with 5 per cent upsetting (Fig. 7*c*), though here the peripheral broadening of the interferences is more marked. Comparison of the X-ray diffraction photographs of the notched bars and the upset specimens thus shows that in the high range the crystals in the surface of fracture have been deformed much as they are by upsetting, while in the low range the mechanism of fracture is evidently different.



Impact energy: 0·3 mkg at −20 deg. Cent.
Cleavage surface under notch down to a depth of about 0·8mm.
Magnified 100 times.

Fig. 3—Formation of crack in the vicinity of the notch. Steel C5, specimen with sharp notch

Closer examination of the diffraction photographs for specimens of steel C5 in the very low range ($K_0 \leq 1$mkg/sq cm) reveals that some of the reflexes are comparatively sharp, while others are more or less blurred, both peripherally and radially. This seems to imply that some crystals in the surface of fracture have an almost undisturbed lattice, having broken almost without deformation, while others have been distorted considerably by plastic deformation before fracture. It may be concluded from a comparison with the diffraction photographs of specimens subjected to low degrees of upsetting that this plastic deformation due to slip is only slight, as at about 2 per cent upsetting there is a peripheral broadening of the interferences similar to that in the notch impact specimens at very low values. The obvious inference is that the differences in the deformation of the crystals in the surface of fracture of a specimen broken at extremely low notch impact values are due to the different crystallographic orientation of the grains in relation to the attacking forces. In the crystals which are unfavourably situated for slip, the cohesive strength in the cleavage plane is then exceeded before the critical shear stress is reached in the planes of slip, whereas in the favourably located crystals the shear stress exceeds the critical value before the normal stress required for brittle fracture is attained in the cleavage plane.

This view was later confirmed by microscopic examination of the specimens of steel C5 broken at −20 deg. Cent. with a step-by-step increase in the notch impact energy in the very low range. The first point noticed was that no appreciable

Table I

Steel quality	C	Si	Mn	Cr	Cu	Yield point, kg/mm²	Tensile strength, kg/mm²	Elongation $l=5d$, per cent
C 5 mild steel...	~0·05	—	—	—	—	~20	~29–33	~40
A St52 CrCu	0·22	0·2	0·99	0b38	0·44	35·2	57·2	27·3

C5 supplied in rods of 20mm diameter, normalised.
A as 30mm plate, normalised.

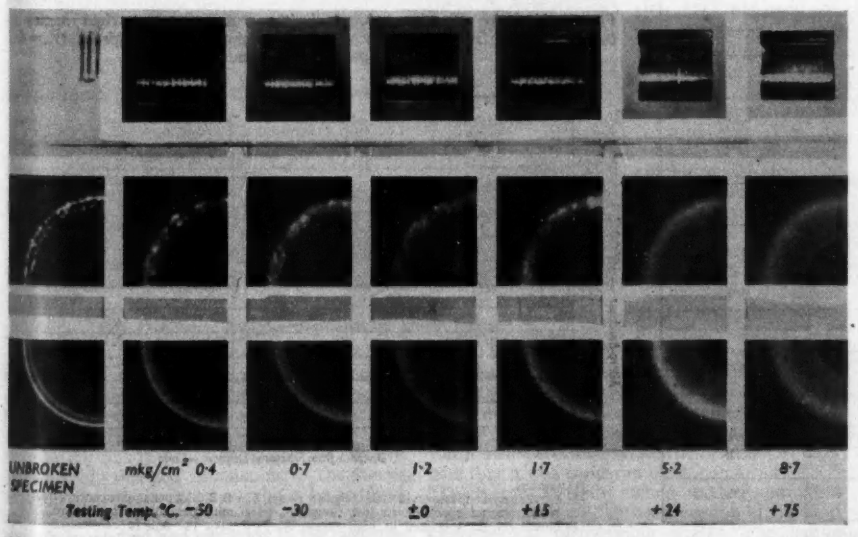
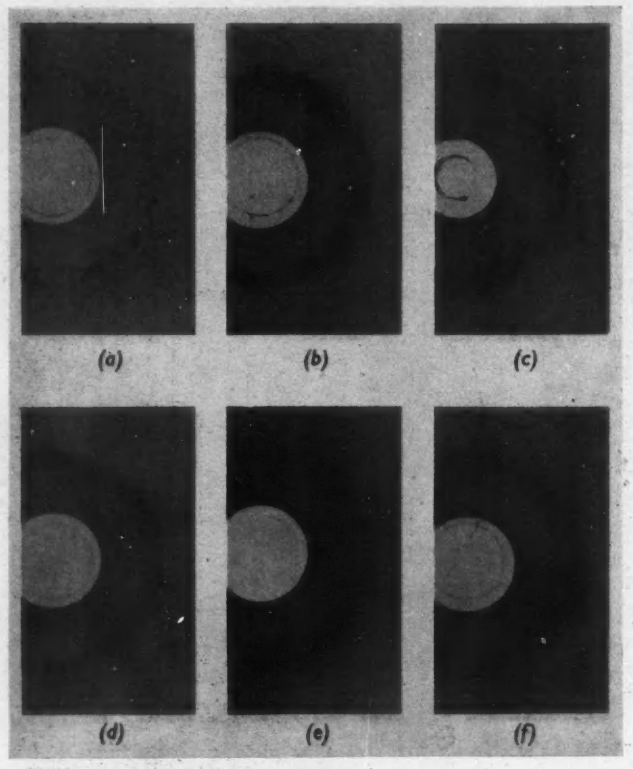


Fig. 2—X-ray diffraction photographs of the surface of fracture of notch impact specimens. Steel A

* W. Felix, *Zur Frage des Stellabfalls der Kerbzähigkeit von Stahl*. Leemann, Zürich, 1954.



(*a*) Material in original state, specimen electrolytically polished.
(*b*) Surface of fracture of girder, photograph taken about 10mm away from start of crack.
(*c*) Surface of fracture of girder, photograph taken about 30mm away from end of crack.
(*d*) Surface of fracture of a notch impact specimen at K_0=0·2 mkg per square centimetre.
(*e*) Surface of fracture of a notch impact specimen at K_0=1·4 mkg per square centimetre.
(*f*) Surface of fracture of a notch impact specimen at K_0=4·7 mkg per square centimetre.

Fig. 4—Co X-ray diffraction photographs of the metal of the girder destroyed by brittle fracture

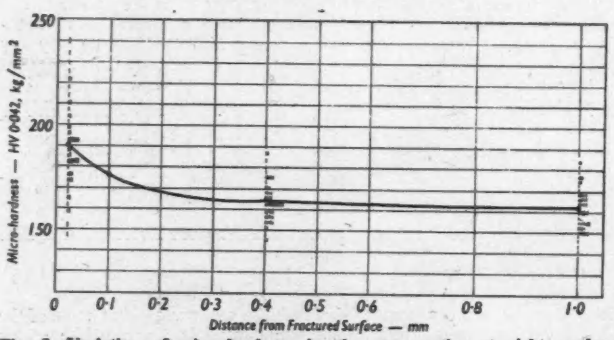
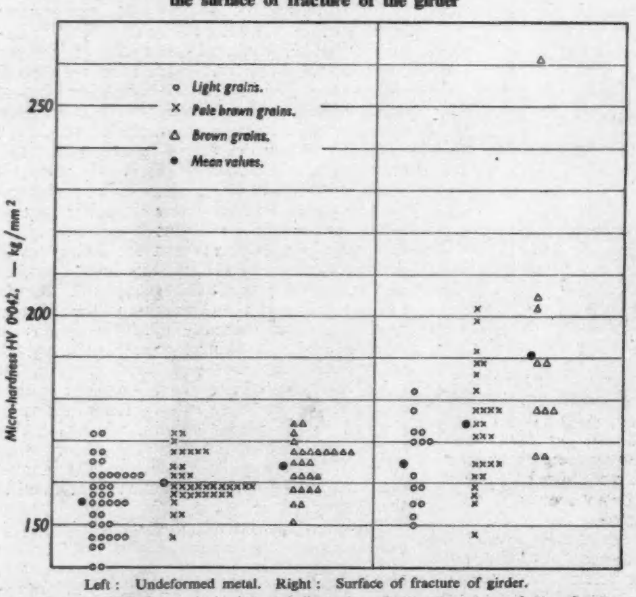
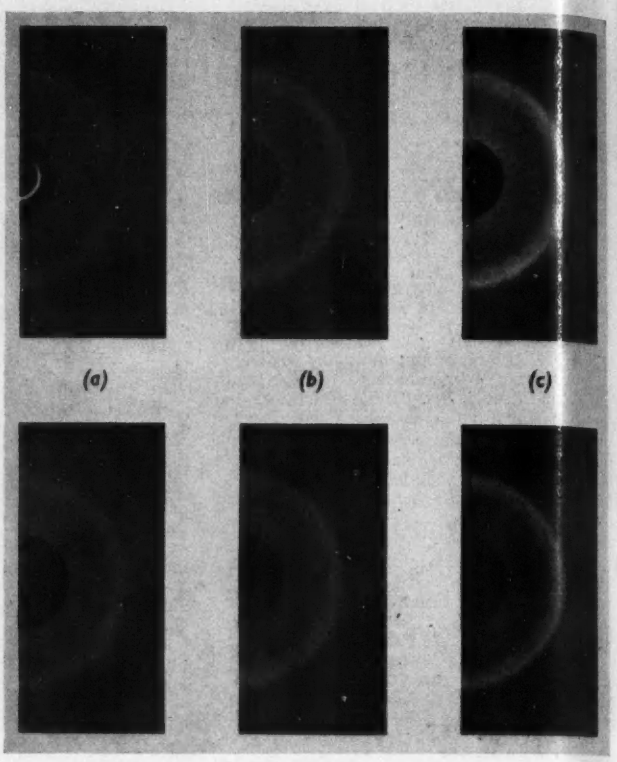


Fig. 5—Variation of micro-hardness in the cross-section at right angles to the surface of fracture of the girder



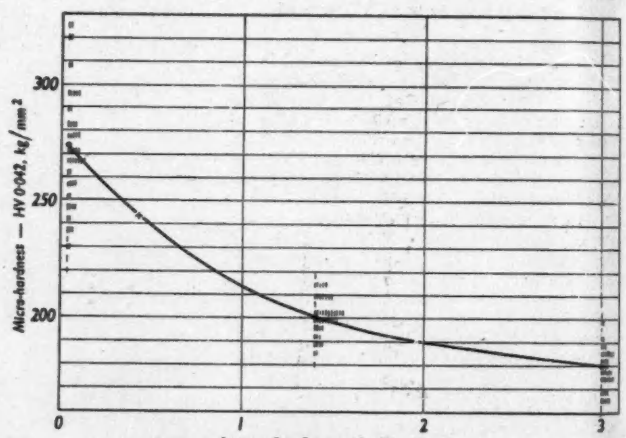
Left: Undeformed metal. Right: Surface of fracture of girder.

Fig. 6—Relationship between micro-hardness and discoloration of the ferrite crystals due to tempering



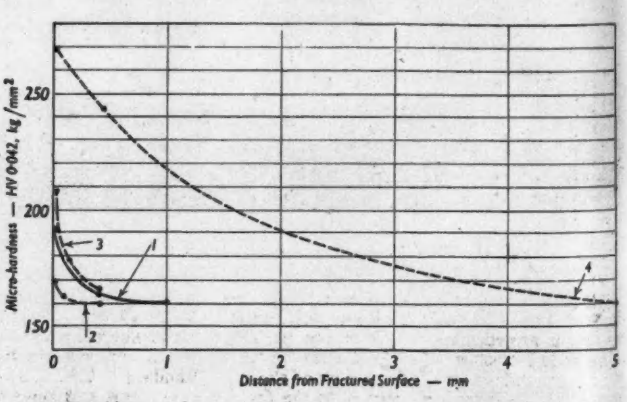
Amount of upsetting: (*a*) 20 per cent; (*b*) 10 per cent, and (*c*) 5 per cent. Stationary film above, rotating film below.

Fig. 7—X-ray diffraction photographs of upset specimens. Steel A



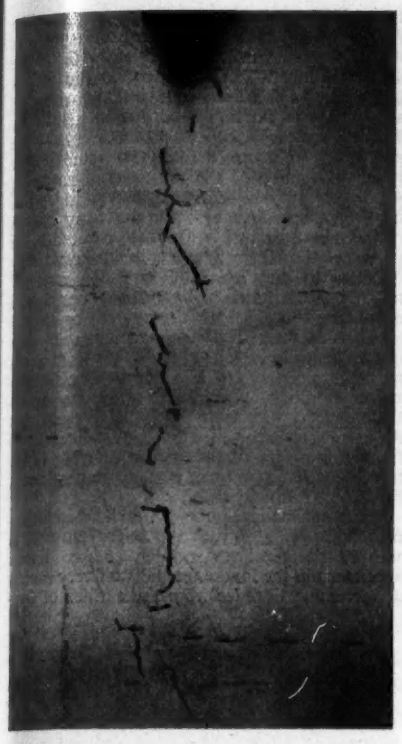
Mean value obtained from fifty impressions.

Fig. 8—Variation of micro-hardness in the cross-section at right angles to the surface of fracture of notch impact specimen from the girder (K_0=4·7 mkg per square centimetre)



(1) Girder.
(2) Notch impact specimen in extremely low range, K_0=0·2 mkg per square centimetre.
(3) Notch impact specimen in low range, K_0=1·4 mkg per square centimetre.
(4) Notch impact specimen in high range, K_0=4·7 mkg per square centimetre.

Fig. 9—Mean micro-hardness values in the cross-sections through the surface of fracture of girder and notch impact specimens



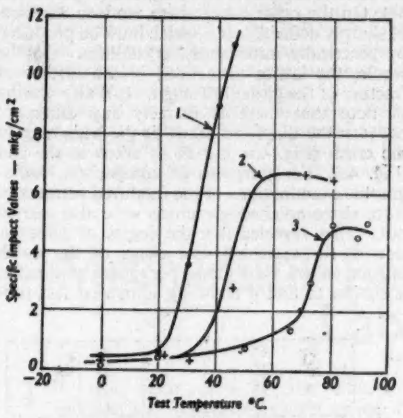
Impact energy : 0·325 mkg at −20 deg. Cent.
Root of notch uncracked, cleavage surface under notch down to a depth of about 1·1mm.
Magnified 100 times.

Fig. 10—Formation of crack in the vicinity of the notch. Steel C5, specimen with sharp notch.

deformation at the root of the notch and no visible crack are observed below a certain critical notch impact energy (0·35mkg).

Figs. 3 and 10 show the structure of specimens tested at sub-critical impact values. Neither of them have any macroscopic crack at the root of the notch, but numerous crystals below the notch have already undergone cleavage. The cleavage planes in most cases run at right angles to the maximum principal stress, though they differ somewhat in each ferrite grain according to its orientation. If the critical notch impact value is slightly exceeded, a crack appears at the root of the notch and then advances suddenly over about two-thirds of the test cross section as a result of the elastic energy storage in the specimen.

It is clear from these observations that in the notch impact test at very low values, and no doubt in brittle fractures quite generally, actual fracture is preceded by the splitting or cracking of individual crystals. This local cracking takes place in crystals in which the planes of slip are unfavourably directed in relation to the forces applied, so that the stresses cannot be reduced by plastic deformation before the cohesive strength is reached and exceeded in the cleavage plane. As the principal stress rises the fracture advances from the cracked crystals, the intact crystals undergoing more or less plastic deformation, according to their orientation, before they give way in their turn. This is in agreement with the varying peripheral spread of the interference points in the X-ray diffraction photographs of the specimens broken at very low notch impact values : the sharp reflexes correspond to the crystallites broken by cleavage, while the broadened interference points are due to those which break later on after more or less marked deformation.



(1) V.S.M. notch diameter 2·0mm.
(2) V notch diameter 0·5mm.
(3) Sharp notch diameter 0·02mm.

Fig. 12—Abrupt transition in the specific notch impact values of specimens taken from the web of girder

Investigation of an I-Girder Destroyed by Brittle Fracture

The following investigations were carried out on a 50cm I-girder, which was destroyed by brittle fracture when it was dismantled after thirty years' service in a boiler-house and was cut with a flame cutter before being put to another use. On the following night the temperature dropped to about 10 deg. Cent. The girder was then accidentally knocked over in the yards, and a crack formed along the whole length of the web, starting from one of the freshly cut edges (Fig. 11). The inner surface of the crack showed the crystalline appearance typical of brittle fractures. The obvious conclusion was that the fracture was due to pronounced brittleness, combined with structural changes and stresses resulting from flame cutting and with complicated internal stresses in the rolled section.

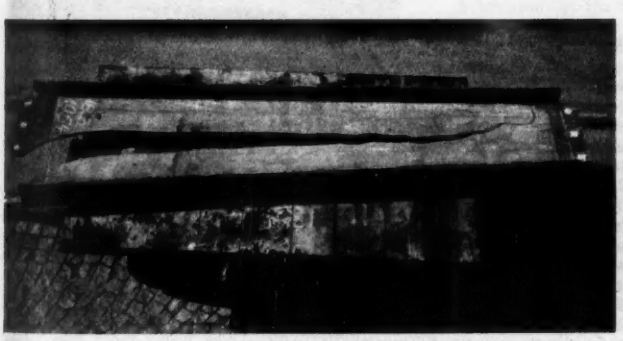


Fig. 11—50cm I-girder destroyed by brittle fracture

The chemical analysis of the girder yielded the following figures :—C =0·09 per cent, Si=0·01 per cent, Mn=0·52 per cent, P=0·058 per cent, S=0·093 per cent, N_2=0·016 per cent. The metal thus was a low-carbon rimming steel with P and S contents which are very high by modern standards. The high N_2 content seemed to indicate that it was converter steel.

A macroscopically etched section showed a zone of pronounced core segregation of the kind characteristic of rimming steels. The tensile test (on round specimens 12mm in diameter and 60mm long) gave the results listed in Table II.

The yield point and tensile strength in the web are unusually high for a steel with 0·09 per cent C, no doubt owing to the pronounced C segregation and the high P and N_2 contents.

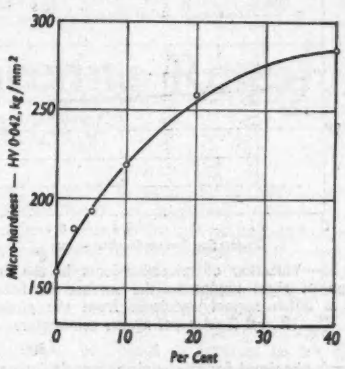
The abrupt transition in the notch impact values was determined by the following means :—

(1) Ten V.S.M. Swiss standard specimens (notch diameter 2mm, notch depth 2·5mm).

(2) Charpy V-notch specimens (diameter 0·5mm, notch depth 2mm).

(3) Specimens with a sharp notch made by knife pressure as proposed by Schnadt (without mandrel).

All the specimens were taken from the web in the longitudinal direction and were tested as supplied and after stress relief annealing (620 deg. Cent. followed by cooling in the furnace).



Mean values obtained from twenty impressions. The micro-hardness increases rapidly with the amount of upsetting.

Fig. 13—Micro-hardness of upset specimens of the I-girder as a function of the degree of deformation

The results of the notch impact tests on the metal as supplied are shown graphically in

Table II

Specimen taken from	Treatment	Yield point, kg/mm²	Tensile strength, kg/mm²	Elongation $l=5d$, per cent	Reduction in area, per cent
Length of web	As supplied	36·7	48·7	29·7	59
Across web	As supplied	34·5	46·9	25·0	52
Length of flange	As supplied	32·3	38·5	39·0	72
Length of web	620 deg. Cent./30ft/furnace	36·7	49·1	32·7	48
Length of web	900 deg. Cent./30ft/air	34·5	50·4	34·2	26

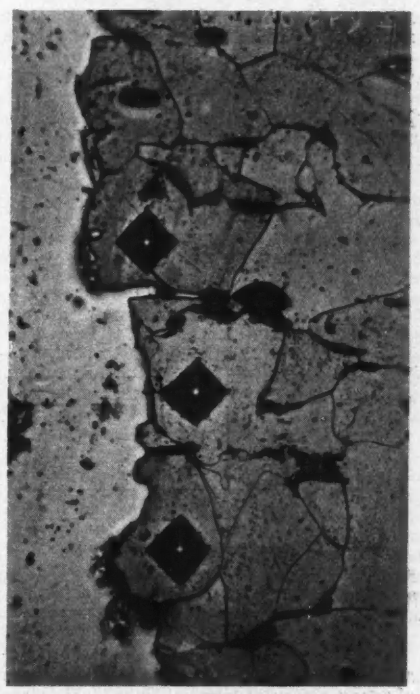


Fig. 14—Position of impressions in the ferrite crystals bordering on the fracture. Magnified 500 times

Fig. 12. As is to be expected, the abrupt transition of the notch impact strength moves towards higher temperatures with increasing sharpness of the notch.

The brittle fracture temperatures (temperatures at which the notch impact values fall to 22mkg/

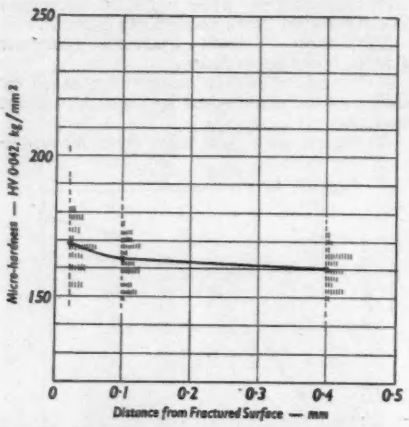


Fig. 15—Variation of micro-hardness in the cross-section at right angles to the surface of fracture of a notch impact specimen from the girder. (K_0=0·2 mkg per square centimetre)

sq. cm) obtained for the various notch forms are listed in Table III.

TABLE III—*Brittle Fracture Temperature, Deg. Cent. (Interpolated for 2mkg/cm²)*

Condition	V.S.M. notch	Charpy V	Sharp notch K_0
As supplied, about ...	25 deg. ...	40 deg. ...	70 deg.

The steel under consideration must be classed as very brittle, for even with the less sharp V.S.M. notch it is already in the range of extremely low notch impact values at room temperature. Its low cohesive strength is definitely due to its metallurgical properties and not to embrittlement caused by ageing, since heat-treatment at 620 deg. Cent. failed to improve it. The destruction of the girder must therefore be attributed primarily to the proneness of the metal itself to brittle fracture.

Comparative Investigation of Crystal Conditions in the Surface of Fracture of the Girder and of Notch Impact Specimens

X-ray diffraction photographs using cobalt radiation were taken both of the unbroken base

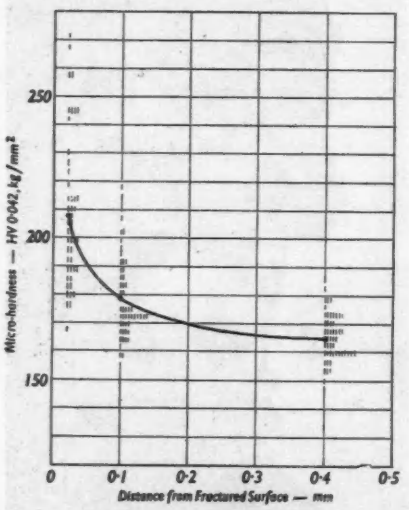
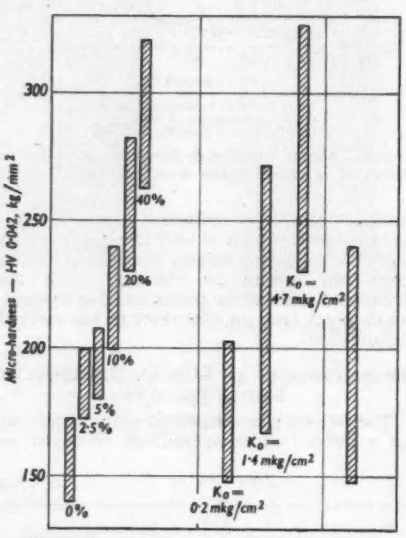


Fig. 16—Variation of micro-hardness in the cross-section at right angles to the surface of fracture of a notch impact specimen from the girder (K_0=1·4 mkg per square centimetre)

metal and of the girder fracture for the purpose of determining what deformation had taken place in the ferrite crystallites. Since the metal outside the fractured zone shows an almost undistorted lattice, as can be seen from the sharp interference points in Fig. 4*a*, it is to be expected that even very slight plastic deformation will be distinctly perceptible. And in fact the photographs of the fractured surface differ considerably from the initial undisturbed condition, some of the interferences appearing blurred (Figs. 4*b* and 4*c*). On the other hand, there are also numbers of sharply defined points which must be produced by practically undeformed crystallites. On the whole, the lattice distortions in the surface of fracture of the girder are slight. It is also worthy of note that there is scarcely any difference between the diagrams taken at the beginning of the crack (Fig. 4*b*) and those taken at the end (Fig. 4*c*). For purposes of comparison, radiographic examinations of the fractured surfaces of three sharp-notched specimens were also carried out. They revealed that the degree of deformation in the extremely low range of the notch impact values, viz. 0·2mkg per square centimetre, is similar to and if anything somewhat less pronounced than that of the girder fracture (Fig. 4*d*), while at 1·4mkg per square centimetre the effects of deformation are definitely more marked (Fig. 4*e*). The notch impact test in the high range (K_0=4·7mkg per square centimetre) yielded a diagram in which the interference points form a diffuse ring, as is to be expected when there is considerable distortion of the lattice (Fig. 4*f*).



Left: Upset specimens.
Right: Girder.
Centre: Notch impact specimens.

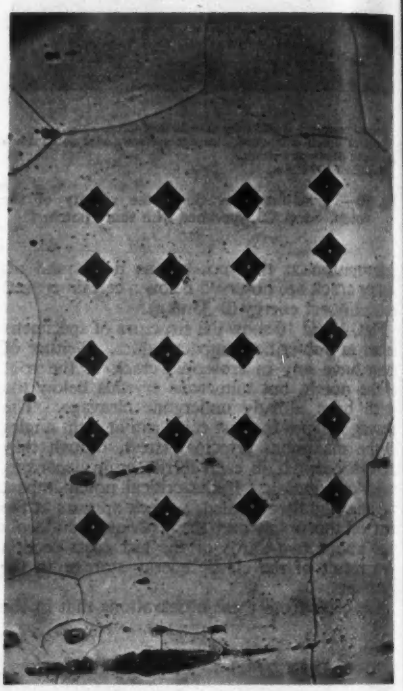
Fig. 17—Scatter of the micro-hardness values in the upset and notch impact specimens

Micro-Hardness Measurements

The degree of deformation of the ferrite crystallites in the fractured surface was also determined by micro-hardness testing. Investigation of upset specimens of the girder material showed that the mean micro-hardness values react appreciably to relatively slight plastic deformation, as Fig. 13 shows. The upset specimens used were cylinders 15mm in diameter and 20mm high, which were upset by 2·5, 5, 10, 20 and 40 per cent. The micro-hardness was then measured on electrolytically polished longitudinal sections down the centre of the specimens with the Hanemann tester. Each section received twenty impressions on different ferrite crystals.

The deformation in the fractured surface of the girder and the notch impact specimens was determined by micro-hardness testing of polished sections at right angles to the surfaces of fracture. These surfaces had previously been nickel-plated to prevent any rounding of the fractured edge during the preparation of the sections. After being embedded in plastic, the specimens were electrolytically polished and fifty impressions were then made in each of them at fixed distances from the fractured edge. The first row of impressions was made exclusively in grains in the immediate neighbourhood of the fracture (Fig. 14), the second set was 0·1mm from the fracture (second or third grain). The results of these micro-hardness measurements are shown in Figs. 5, 8, 15 and 16. The scatter of the hardness values for the various crystallites in the immediate neighbourhood of the surface of fracture is here most instructive. In the girder (Fig. 5) some of the crystals are practically undeformed (hardness values in the range of scatter of the undeformed material), while others show definite cold working. This confirms the findings based on the X-ray analysis of the microstructure, which also pointed to the presence of deformed grains beside practically undeformed ones. In the very low range of notch impact values (K_0=0·2mkg per square centimetre, Fig. 15) only very few crystallites are harder than the undeformed metal. The impact test with somewhat higher values (1·4mkg per square centimetre, Fig. 16) already shows a bigger number of cold-worked grains in the surface of fracture than was found in the girder. As was to be expected, all the crystallites in the fractured surface of the specimens lying in the transition range (4·7mkg per square centimetre, Fig. 8) are distinctly deformed.

It is clear from the curves for the mean hardness values (Fig. 9) that the micro-hardness in the brittle fractures (girder, notch impact specimens in the low range) falls off very rapidly at increasing distance from the surface of fracture. On the other hand, in the ductile fractures (notch impact specimens in the transition to the high range) it falls off slowly with depth, attaining the values of the undeformed material only at about 3mm. Judged on the basis of the mean hardening at the surface of fracture, the girder fracture lies between the two notch impact specimens in the low range (0·2mkg and 1·4mkg per square centimetre), which is in agreement with the X-ray findings.



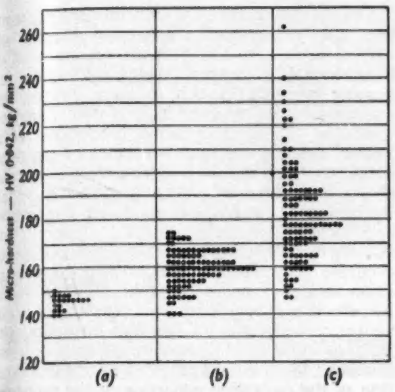
p=42 gr. Magnified 250 times.

Fig. 18—Micro-hardness impressions in a coarse ferrite grain produced by recrystallation

The amount of deformation which has taken place at the surface of fracture can be estimated by comparison of the micro-hardness measurements with those of the upset specimens. It appears from Fig. 17 that the ferrite crystals at the surface of fracture of the notch impact specimens for K_0=0·2mkg per square centimetre have been deformed by 0 per cent to about 5 per cent, while deformation in the girder fracture extends from 0 per cent to about 10 per cent.

An attempt was also made to determine the

cause of the comparatively wide scatter of the hardness in one and the same specimen. Even the undeformed specimens have a fairly wide range of scatter which, assuming accurate measurement, must be due in the main to hardness anisotropy (dependence of the hardness on the crystallographic orientation). To prove this, the micro-hardness of a coarse grain of ferrite produced by recrystallisation was measured by making twenty impressions (Fig. 18). The measured values showed a scatter of only ±5kg



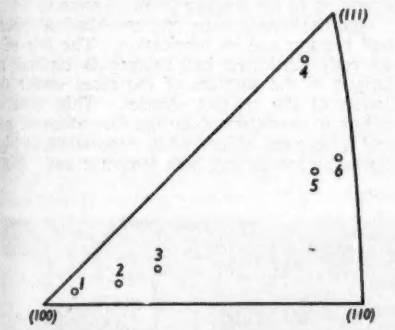
(a) 20 impressions in a grain of the undeformed metal.
(b) 100 impressions in 100 different grains of the undeformed metal.
(c) 100 impressions in 100 different grains along the surface of fracture of the girder.

Fig. 19—Scatter of the micro-hardness values in ferrite crystals

per square millimetre about the mean (Fig. 19(*a*)), while measurements on a larger number of grains, even in the undeformed material, revealed a much bigger scatter of about ±15kg per square millimetre (Fig. 19(*b*)). This must be ascribed primarily to anisotropy.

The deformation during fracture causes an increase both in the mean hardness and in its scatter, as the ferrite grains obviously undergo differing degrees of hardening according to their position (Fig. 19(*c*)).

Some information on the relationship between crystal orientation, hardness and deformation



Stereographic projection : 1, 2 and 3 light grains; 4, 5 and 6 dark grains.

Fig. 20—Dependence of the discoloration of the ferrite crystals on their orientation

was obtained from the following experiments. One-hundred micro-hardness impressions were made in a section of the undeformed material and this was then tempered for two hours at 230 deg. Cent., after which the crystallographic orientation of the ferrite grains was distinguishable by the varying degrees of brown discolouration. If the ferrite crystallites are now divided into three categories on the basis of the estimated degree of discoloration (light, medium and dark grains), a relationship with the hardness is apparent, as the lighter grains are on the average somewhat softer than the darker ones (Fig. 19). The scatter of the hardness values within any one category of crystals—for instance, the light grains—will, of course, be greater than in individual crystals, as it is also influenced by the directional anisotropy within the area tested, which is not revealed by the discoloration due to tempering.† In the crystallites along the surface of fracture (Fig. 6, right) this relationship of colouring and hardness is also evident, the increase in hardness due to cold working clearly being somewhat greater in the dark grains than in the lighter ones. This confirms the assumption made in the first part of this article, namely that the deformation of individual crystallites in brittle fractures depends to a large extent on their orientation.

Finally, it was attempted by X-ray analysis to determine the preferred crystallographic orientation of the light and dark grains. Three light and three dark grains of a specimen subjected to coarse-grained recrystallisation and subsequent tempering were photographed by the *Laue* method, and the poles of the crystal planes were entered in stereographic projection. Fig. 20 shows clearly that in the light grains it is primarily the faces near the (100)-plane that lie in the plane of the section, while with the dark grains it is the faces between (111) and (110).

While the above results give no quantitative information as to the dependence of the deformation of ferrite crystals on their orientation in brittle fractures, they at least firmly establish the fact that the position of the crystals decisively affects the mechanism of deformation and fracture.

† T. Geiger, "Einfluss des mechanischen und electrolytischen Polierens auf die Mikro- und Makrohärte von metallischen Werkstoffen. *Schweizer Archiv* (18), No. 2, 1952.

Mechanical Engineering Research Laboratory

THE first open days of the Mechanical Engineering Research Laboratory at East Kilbride, were held on Thursday, September 20th and Friday, September 21st, when representatives from industrial research departments, research associations and Government departments were given an opportunity to see the facilities and inspect the wide range of work now in progress. This laboratory was set up in 1947 to carry out an extensive programme of fundamental and applied research complementary to that undertaken in industry, the universities and other research organisations, as well as to undertake special investigations for private firms. Its work is guided by the Mechanical Engineering Research Board, the members of which are scientists and engineers from industry and the universities, who, with their special knowledge and experience, enable a close contact to be maintained with the country's needs for mechanical engineering research.

The laboratory is situated some eight miles from Glasgow at the south-east extremity of the new town of East Kilbride, and its site consists of two areas of building land intersected from north to south by woodland and rough hill pasture which is unsuitable for building purposes. The east portion is about 27 acres in extent and approximately 25ft higher than the west portion, which comprises about 25 acres of land suitable for development. The remainder is rough hilly or wooded land which has been allowed to remain in its natural state as far as possible. Although the total area available for development is adequate to meet the long-term building programme, site conditions precluded a compact development scheme, and the establishment is planned in two separate groups connected by a main east-to-west road which accommodates the main drainage and engineering service ducts.

The work of the laboratory is arranged in seven main divisions concerned with : properties and strengths of materials ; mechanics of solids, stress analysis, and vibration ; mechanics of fluids including hydraulic machinery ; lubrication, wear and mechanical engineering aspects of corrosion ; mechanisms, engineering metrology, and noise control ; mechanics of formation and machine shaping of materials ; heat transfer, heat exchange apparatus, and applied thermodynamics ; and a workshop. At present two of the main buildings—the materials section and the hydraulic machinery building—have been completed ; the workshop is being extended, and the heat transfer building and the mechanisms and metrology buildings are in course of construction. For this reason some of the divisions are housed temporarily in parts of the completed buildings, and certain sections of the lubrication and the machining research divisions are situated for the time being at Thorntonhall, a few miles distant from East Kilbride.

For the open days, comprehensive groups of demonstrations and exhibits were arranged in the various divisions to give visitors an insight into the work in hand and the way in which the establishment is organised. There was not sufficient time available to make detailed examination of specific technical aspects of the work, but an appreciation was given of its broad scope even at this relatively early stage in the life of the establishment. Naturally, this being the first visit by many to the new laboratories, there was as much to be found of interest in the facilities as in the work, and but few could fail to be impressed by the great potential there will ultimately be for research when all the laboratories are completed. In the following notes we deal briefly with some of the facilities of the laboratory and some research items at present being studied.

Materials

The materials building, which is at present being used for general experimental work, will eventually become the main laboratory for research on engineering materials. An important part of this division's work is assessing the causes of failure of components which have fractured in service, and from the wide variety of failures to be seen in the laboratory certain facts were evident. First, it was shown that some designers are still unaware of the dangers of sharp changes of section and other stress raisers, despite the prominence that fatigue studies have had in the technical literature ; secondly, that satisfactory design may easily be nullified by poor execution during manufacture. Further stresses in service are often of a different nature from those envisaged at the design stage, and it is rarely that the material is at fault.

In investigations on the strength of screw threads, research has included investigations of the static and fatigue strength of threaded combinations, and of their tightening characteristics (that is, the relation between tightening torque and bolt tension, and tendency to seizure). Results of particular interest are : the small effect on strength of variations in geometrical form of thread ; the markedly beneficial effect of cold rolling ; and the absence of any serious detrimental effect on strength of large deviations from theoretical thread form as represented by large angle errors and heavy truncation. These deviations, it is stated, may even result in a gain in strength, although they have an adverse effect on tightening characteristics. There would appear to be an optimum depth of thread appreciably less than that generally thought to be necessary.

Much work is being done on the behaviour of materials at high temperatures, and investigations in progress cover creep under complex-stress systems and general loading conditions at elevated temperatures ; relaxation under complex-stress systems at elevated temperatures ; creep to fracture under complex-stress systems at elevated temperatures ; and the creep behaviour of structural elements.

Mechanics of Fluids

The hydraulic machinery building is stated to be the largest and most advanced of its kind in the world. Its equipment includes open circuits for performance tests on water turbines,

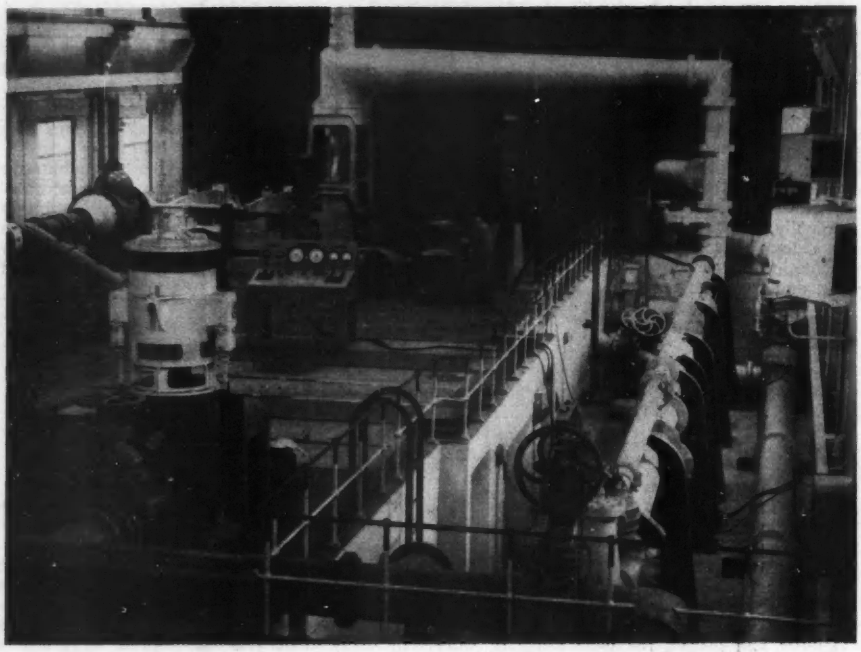


Fig. 1—Open-circuit test bay of hydraulic machinery building

pumps, valves, and pipelines, and for calibrating flow measuring instruments; a closed circuit is installed for cavitation research on centrifugal and mixed flow pumps, and another for cavitation research on water turbines. The open circuit test bay of this building is illustrated in Fig. 1.

The main hydraulic test bay is 120ft long by 50ft wide, and has 1500 square feet of test bed area for mounting equipment. Service pumps deliver water at up to 11,000 gallons a minute from a 60,000-gallon sump to either a 45ft constant head tank or to a variable head tank in which the head can be set at any value between 12ft and 40ft. Pumps mounted above the variable head tank can be tested with suction lifts up to 30ft. Water returns to the sump either directly or through pipelines of 8in, 14in or 18in diameter where flowmeters can be calibrated at flow rates up to 12,000 gallons per minute. The rate of flow is measured by diverting the water for a known time into the 30-ton weighing tank, to be seen in the left background of our illustration. For friction and flow measurement tests, 700ft of 20in diameter pipe linked to the main circuit has been installed outside the building.

The closed circuit for research on pumps under cavitation conditions can accommodate centrifugal or mixed-flow pumps up to 20in inlet diameter, with a maximum head of 600ft, flow rates up to 7500 gallons per minute, and inputs up to 350 h.p. The water turbine closed circuit enables models up to 250 h.p. and 20in runner diameter to be investigated at heads from 10ft to 200ft. For low heads, the water is circulated by a variable-pitch axial flow pump and by a centrifugal pump for high heads. To reabsorb air bubbles produced at the cavitating pumps and turbines these two closed circuits incorporate vertical tanks 12ft diameter and 60ft long situated below ground level.

An aerodynamics laboratory forms an integral part of this division to provide a relatively inexpensive means of initially testing pump, turbine and other models made of wood or sheet metal, and using air instead of water as the working fluid. Its equipment includes the three-limbed wind tunnel to be seen in Fig. 2; it can be supplied with up to 30,000 cubic feet of air per minute at 15 lb per square inch by an axial flow fan. Provision is made for a 3ft diameter open jet blower tunnel for instrument calibration and research; 65ft of 3ft diameter piping for measurements inside ducts; and a 9ft by 6ft suction nozzle for connection to model water turbines.

Investigations are in progress to determine the limitations of the technique of using air for hydraulic machinery research; a series of tests on a small centrifugal pump using water yielded a great deal of information on flow patterns in the inlet and discharge pipes and at the outlet from the impeller. These tests are being repeated on a geometrically similar model of twice the size using air as the working fluid. Comparison should afford useful information on the reliability of air tests for predicting water performance.

Parallel research is proceeding on the performance of blades for axial-flow machines. Although air is used for the experiments, the results may apply equally to pumps or fans. Blading design data can be determined in a specially designed rig in which the blades are mounted on a hub and rotated at speeds up to 700 r.p.m. by a compact 15 h.p. oil motor mounted in the hub fairing. By varying the rotational speed of the blades and the throughflow of air from a 100 h.p. blower fan, blade working conditions, ranging from pump to turbine operation, can be simulated. Blade performance is obtained from pressure and velocity surveys upstream and downstream of the blade row. It is hoped that this method of blade testing will enable the performance of machines to be predicted more accurately. Should air testing prove satisfactory, a considerable amount of preliminary work on new designs of pumps can be done cheaply and quickly before final investigations using water are made.

For the study of oil hydraulic systems and equipment there is a separate large laboratory for oil and special fluids. It is provided with two 2000-gallon oil storage tanks from which oil is supplied to three test benches and two test beds equipped for carrying out a wide range of research on oil pressure systems.

Lubrication

The division concerned with lubrication, wear and the mechanical engineering aspects of corrosion, has for the present been installed at Thorntonhall. The work being carried out on bearing research in this division includes an interesting visual study of hydrodynamic lubrication. In the hydrodynamic lubrication of a journal bearing, the load is carried by the pressures generated in a thin film of lubricant under shear, and the load carrying capacity of the bearing and the friction produced depend on the extent of this lubricant film. A transparent bearing technique has now been developed, using accurate glass bearing bushes and ultra-violet illumination to make the thin oil film visible by fluorescence. With an electronic flash source, photographs of the film formation can be taken under conditions of steady or of dynamic loading. Photographs reveal the form and position of the cavitation occurring in the unloaded part of the oil film, and have shown that the film is seldom complete in a 360 deg. journal bearing. This applies not only to steadily loaded bearings, where the most recent theoretical estimates of load capacity are based on a partial pressure film, but also to bearings under rotating or alternating loads, where previously it had been considered that the film might remain unruptured. Theoretical estimates of friction loss, based on the assumption of a continuous film, are therefore too high.

The transparent bearing technique permits the study of the influence of oil entry conditions on film extent, a topic on which theory gives little guidance. The oil meniscus at the bearing sides has been found to play an important part, both under starved and adequate oil supply conditions. The recirculation of oil between the bearing oil film and the meniscus leads to a diminution, as compared with theory, in the oil supply required, and can permit hydrodynamic operation in the absence of an oil supply.

Another investigation concerns the high-speed ball bearing and its lubrication. The life of a correctly lubricated ball bearing is limited by fatigue of the surfaces of the races under the action of the contact stresses. This type of failure is characterised by the formation of pits and it becomes of increasing importance at high operating speeds and high temperatures. Little

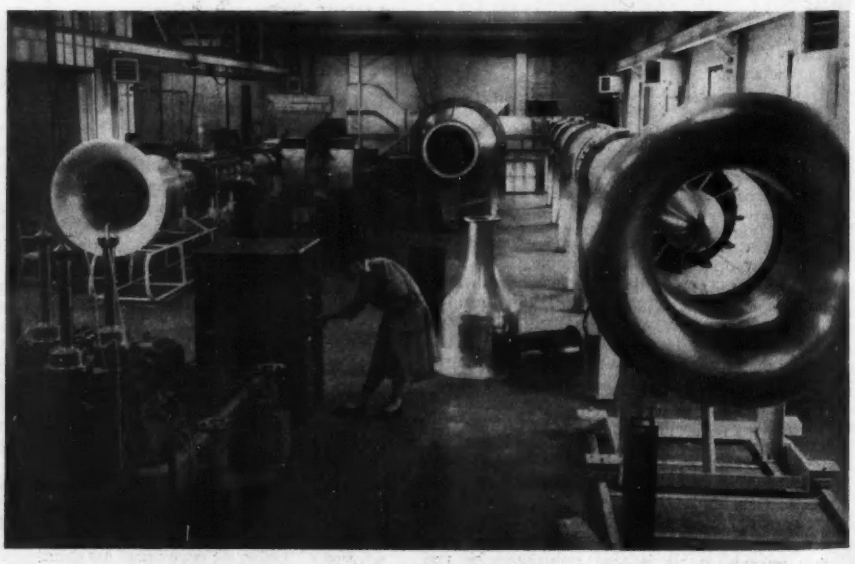


Fig. 2—Three-limbed wind tunnel in the aerodynamics laboratory of hydraulic machinery building

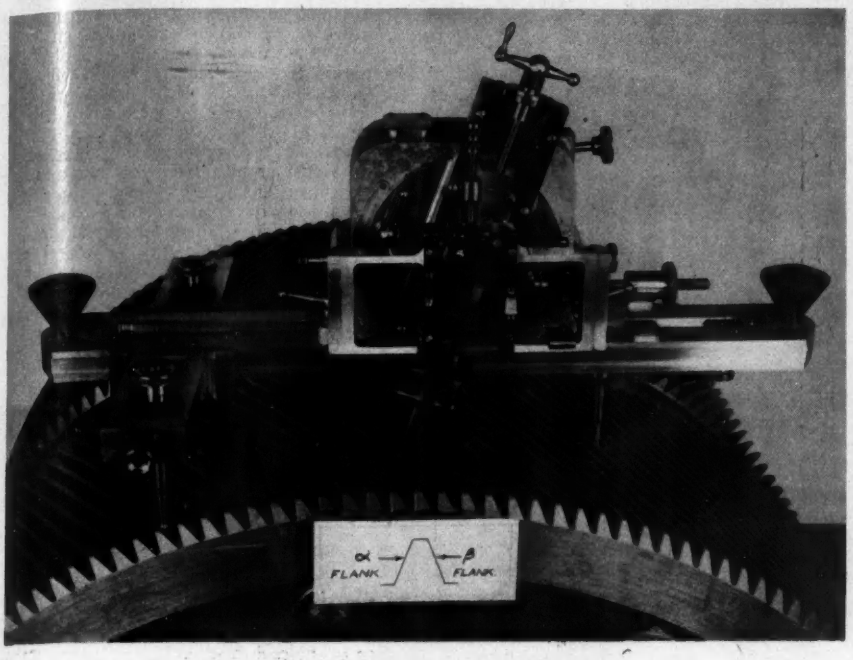


Fig. 3—Gear tooth profile gauge for large marine gears

basic information is available on the mechanism of pitting and a test rig has been constructed for studying pitting in high-speed ball bearings. On this rig the factors which determine the onset of pitting are being studied for a range of lubricants and a series of steels in rolling contact.

The new design of testing machine developed is capable of testing bearings at speeds up to 30,000 r.p.m. with axial loads up to 2000 lb. On it two kinds of specimen can be tested. Complete ball bearings up to 2in external diameter may be used to study the effect of different lubricants and elevated temperatures. For investigating the way different materials behave, a simplified angular-contact bearing has been designed. This bearing comprises a shaft with conical ends, each end running against three balls within an outer race. This simple design reduces the difficulties which might arise in the manufacture of complete bearings in special steels.

Radioactive tracers are being used to study boundary friction by making one of two metal surfaces in frictional contact radioactive, and measuring the quantity of radioactivity found on the previously inactive surface. Radioactive isotopes are used to investigate metal transfer when two surfaces rub together, and how this is affected by sliding velocity, surface roughness, and the nature of the lubricant. There is much experimental evidence that the coefficient of friction is not independent of the relative velocity of sliding, particularly when there is a lubricant between the surfaces. The variation with velocity may be due to the rate of breakdown of local high-points and shearing of the lubricant. Experiments are being carried out in a kinetic boundary-friction machine in which a hemisphere of radioactive copper is moved under load over a flat mild steel specimen. Oleic acid and pure mineral oil are the lubricants and steel specimens with surface finishes from 1 to 40 micro-inches are being used. The results so far have shown that the amount of radioactive copper transferred to the steel specimen, and the coefficient of friction, depend on the sliding speed and the lubricant. This work is being continued to see how far the variation in coefficient of friction can be related to these two factors.

For a study of fretting corrosion, the form of wear which occurs when there is small but repeated relative movement between mating surfaces, a multiple fretting machine has been developed for long-duration tests. The nature of the wear occurring during the initial stages of fretting has been studied under the electron microscope. It has been found that with steel specimens the first wear particles are primarily due to the ploughing action of minute surface protuberances, which are considerably harder than the surface as a whole and may be due to intermetallic welds or to the hard carbide phase of the steel. Investigations in connection with cast iron bearing surfaces have shown that possibly the wear of machine slides during periods of idling and vibration may start through fretting corrosion. The resistance against fretting of a series of cast irons is under investigation in the laboratory, and results so far have shown that cast irons vary considerably in their fretting resistance when dry, the amount of damage differing in some instances by ratios of about 20 : 1. When lubricated these variations are reduced to about 2 : 1. There is insufficient evidence so far to show the effect of phosphorus content. The ability of various lubricants to promote resistance against fretting is also being investigated, and whilst the presence of a lubricant is usually beneficial, its nature and composition are stated to be less important.

Metrology

A rack-type gear measuring equipment has been developed by the metrology division as a production measuring instrument, and its results are stated to be less limited than those from the conventional dual-flank gear-mesh testing machine. Owing to the cost and difficulty of obtaining suitable master gears, the present instrument uses a master rack as the datum for measurement, and the results obtained are derived from single-flank meshing of the gear under test with the master rack. Using this equipment, quantitative evaluation of cumulative and adjacent pitch errors, together with profile errors, are possible, and the instrument may also be used for the more usual dual-flank mesh tests.

Earlier methods for measuring the errors in tooth profile of large marine gears have been based on a simple copying mechanism, in which the shape of the tooth is scribed on a smoked glass plate when a stylus is traversed round the tooth profile. In the absence of mechanical magnification within the recorder itself, the overall magnification at which the records can be examined and measured on an optical projector is ×50. A new gear tooth profile recorder developed is shown in Fig. 3. It is based on measurement of the departures of the involute form from a straight line datum, provided by the movement of an accurate slide. The slide carries a scribing mechanism which, in this case, produces a trace on a smoked glass plate having a magnification of ×10 normal to the slide traverse direction. Subsequent examination on an optical projector allows for comparison with a nominal form at a magnification of ×500.

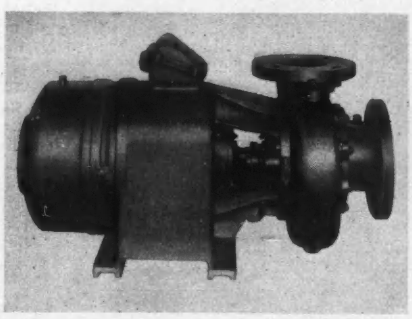
Another instrument has been developed to record continuously the errors in the alignment of the hob saddle motion of gear hobbing machines. It incorporates a photo-electric gauging device for mounting on the hob saddle to operate in conjunction with a vertical reference wire freely suspended from some convenient point. A corrector bar, included in the gauge head, is used to correct automatically for errors arising from the fact that the table axis may not be truly vertical. Results are recorded on a linear chart which indicates directly the errors in alignment between hob-saddle traverse and table axis. The method has the advantage that measurements can be made in close proximity to the cutting zone of the hob and can be applied with equal facility to all sizes of machines. The sensitivity of the gauging system is such that variations of the order of 0·0001in can be readily detected.

A continuous pneumatic gauging equipment developed for gauging razor blades during production has the gauging head fixed on the production line so that blades pass through it. Its indicator dials are placed at some convenient point near the machine. These dials are calibrated to indicate average blade size and the time constant of the instrument is deliberately chosen to be about two seconds, so that general trends of size, and not individual blade sizes, are indicated. The instrument can be used as part of a closed-loop system in which the setting of the machine is controlled automatically to maintain blade size within specified limits.

Centrifugal Pumping Set

We illustrate below one of the "PumPak" motor-driven pumping sets now being made by Sigmund Pumps, Ltd., Team Valley, Gateshead, 11, in a number of models covering heads up to 150ft and outputs up to 500 gallons a minute. These are designed to constitute easily installed, self-contained, compact units suitable for a wide field of application.

The pump assembly is mounted on a rigid support body at one end of which is bolted and flanged the volute casing and at the opposite end the motor rear casing. These main support and casing units, like the impeller and the flanged suction cover, are made of high-grade, close-grained cast iron. The pump impeller and the motor rotor are mounted on a single high-tensile steel shaft carried on ball bearings and fitted with a renewable bronze sleeve where it passes through the pump stuffing-box. A deep section stuffing-box has an internal sealing arrangement whereby water is fed from the



Single-shaft centrifugal pumping set with 4in branches

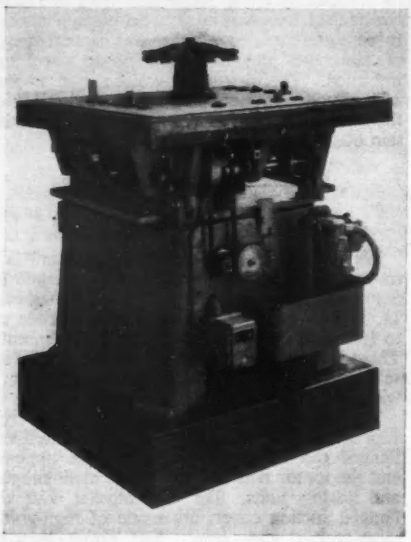
pressure side of the pump to the lantern ring, which has packing rings on both sides. A water thrower is fitted on the shaft to prevent liquid entering the bearings and its action is supplemented by a flow of air from the driving end of the motor.

An axial suction flange is used and the discharge flange is set in a vertical position as a standard arrangement, although it can be arranged readily in any of eight positions. The pump itself is designed to operate with equal efficiency in a horizontal position or wall-mounted in a vertical position with the motor uppermost.

Basic Automatic Indexing Machine

We illustrate below the latest design of the "Compass" automation base, a machine developed by Bristol Repitition, Ltd., Feeder Road, Bristol, 2, to form the foundation of special-purpose semi- or fully-automatic indexing machines for up to fourteen operations. These basic machines can be fitted with unit heads or other suitable tooling for carrying out a variety of operations which may include either straight-forward operations such as milling, drilling, tapping, slotting, chamfering; or such operations as forming, bending, flanging, piercing, clearing, cleaning, and marking. Alternatively, parts may be fed in at various stages, either manually or mechanically, and assembled into a composite form. The machine is built to provide an easy method of synchronising and co-ordinating the sequence of operations with the movement through the machine of the workpieces.

The machine has a substantial cast iron table, 3ft square, mounted on a suitable frame. The spindle of an indexing assembly mounted centrally in the table is 2in diameter and supported in heavy ball and roller bearings. This spindle

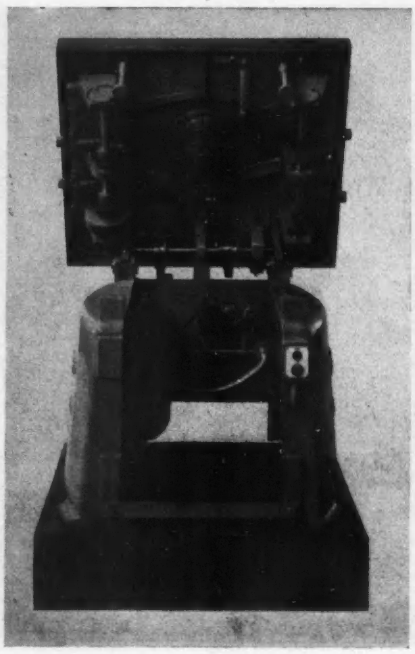


Rear of machine with guards removed, to show the suds pump and pick-off gearbox. Six cam-operated push rods can be seen projecting up through bushes

has at its upper end a flange to which there can be fitted a suitable head, carrier or table for the workpieces. A ratchet wheel and dial plate that control the indexing motions of the head can be seen in our second illustration which shows the underside of the table. With the standard equipment the wheel and plate supplied will operate with six, eight, twelve or twenty-four stop stations per revolution of the head, but wheels and plates can be supplied to give alternative indexing movements.

The ratchet wheel through which the head is indexed is actuated by a cam-operated pawl, and the cam profile can be arranged to vary the indexing times in relation to the total cycle times to reduce idle periods to a minimum. A cam-actuated stop is fitted to prevent head overrun and a pneumatic damper avoids undue loads being imposed on the stop mechanism.

On the underside of the table on each of three sides there is a camshaft supported on sealed ball bearings, and the three shafts are coupled together by bevel gears to run at a common speed. On these shafts there are mounted the cams which actuate the indexing head, and provision is made for mounting up to fourteen other operating cams. These operating cams are attached to camshafts which actuate push rods passing through guide bushes in the table. From any one of these push rods a vertical straight-line motion can be taken to operate a work unit or tools set relatively to a work station on the head. The push rods are spaced round three-quarters of the circumference of the work head, leaving the remaining quarter



Machine with table open and drip-tray removed, showing the camshafts and indexing mechanisms

open for work feeding and finished component removal. Simple plate cams are used on the machine and their fitting and adjustment can readily be effected. When any one of the push rods is not required its bush hole can be blanked off by a plug to leave a flush table surface.

A 1 h.p. motor in the base drives the machine through vee belts, and a pick-off gearbox has four wheels which can be changed to give the desired cycle time. The normal range of gearing gives a series of cycle times between 0·250 seconds and ten seconds, but the gearing or motor speed can be modified to extend this range.

Spline Rolling

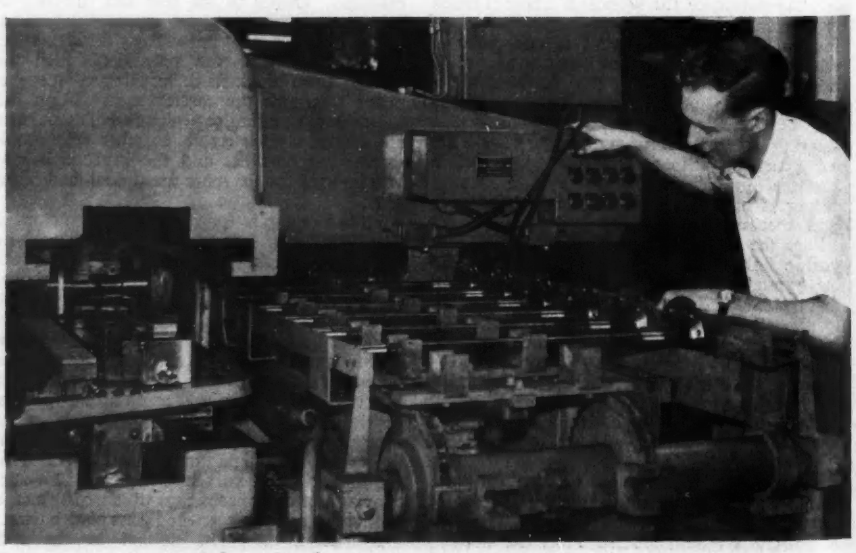
The remarkably rapid process of rolling splines on to a shaft has now been applied to the manufacture of half-shafts for automobile rear axles by the Ford Motor Company. The plant used is the "Roto-Flo" machine of the Michigan Tool Corporation.

In this process, the shaft is journalled between centres, and the cross-section required is generated by two racks, moving in opposite directions past the shaft and rolling the shaft between them. The forming racks are driven by hydraulic pressure and constrained to move with identical velocities by a pinion coaxial with the shaft and engaging racks cut on each moving table. The forming racks are mounted on wedges which can be moved axially to give a fine adjustment, monitored by a vernier, of the distance between the shaft centre and the tool. The forming racks must be adjusted individually to the correct setting: they are clamped by screws, and held in the correct transverse plane against a solid spacer of the required size. A yield under load of about 0·003in is anticipated by the maker. In operation, a shaft is pushed forward through a tapered guide on to the fixed centre by the outer centre, which moves along a cantilevered over-arm. When the shaft is in position, electrical interlocks allow the working stroke to commence. At the end of the stroke, the shaft is withdrawn and the tables return to the starting position: a fresh workpiece is loaded automatically from a linked conveyor system. Cycle time is 15 seconds.

The machine has self-contained hydraulic oil, cutting oil, and lubricating oil systems. The basic structure is that of a long C-shaped girder, the tables moving in the jaws of the C, but ties are added across the gap in the front of the body. The tables travel on flat slides. The forming racks rise progressively from the leading end to the full working depth, and more than one circumference of full depth rack is provided (one half, clearly, is the minimum). This provision not only gives a long service life to the racks, but also imparts an impressive surface finish: rolling En18A material hardened to 325 Brinell, Ford Motor Company obtain a finish of 6 micro-inches and anticipate a tool life, without regrinding, of 25,000 to 30,000 workpieces.

The blanks for this process are ground to a diameter between 1·0005in and 1·002in. The profile imposed is that of a serration with a pressure angle of 45 deg.: the pitch circle diameter is 1in and true involute form obtains outside a diameter of 0·9708in. On a batch of a score of test pieces, eccentricity and taper were within 0·0005in. Taper is associated with splines cut at the end of a shaft having no relief at the inner end of the splined length.

Sections through rolled shafts show that the grain flows, as would be expected, round the serrations. That this cold working improves the impact resistance of the component has been established by tests in actual cars. Under deliberate and extreme shock loading of the transmission, the life of the rolled shaft with twenty-four serrations of root diameter 0·958in was twice that of a shaft with sixteen splines 0·921in root diameter. In each case the mode of failure was the same, the shaft shearing immediately outside the differential. It is, of course, the synchromesh gearbox that opens the way to abuse of the transmission, and the rolled shafts, with broached serrated differential bevels, have now superseded hobbed shafts on Mk. II "Consul," "Zephyr" and "Zodiac" cars.



Half shafts in place in the conveyor: the lower rack is approaching the workpiece

Industrial and Labour Notes

Overseas Trade

The Board of Trade has announced that the value of United Kingdom exports in August was £253,400,000, which was about £13,000,000 less than in July and 4½ per cent below the average for the first seven months of the year. It is usual, of course, on account of annual holidays, for exports to be lower in August, but this year the fall was actually less marked than in recent years. But the Board of Trade says that this is accounted for by the fact that August this year contained twenty-seven working days, whereas there were only twenty-five working days in July.

If July and August are taken together, the recorded value of exports was 6½ per cent higher than in the comparable months of 1955. The 1955 figures, however, contained an element of the recovery of exports from delays caused through the railway and dock strikes. But allowing for that, and also discounting the further repayments of silver bullion to the U.S.A. in the July-August figures this year, the underlying increase in value was probably close on 10 per cent, which, according to the Board of Trade, was very much in line with the increase shown in the first half of this year. Furthermore, the increase was made up, again much as in the first half-year, of a rise in the volume of exports of rather more than 6 per cent and a rise in prices of about 4 per cent. An examination of the commodity pattern of trade indicates that there was a fall of 4½ per cent in engineering exports in July and August; in the two months they averaged £104,500,000. The reduction occurred in machinery other than electric, road vehicles and aircraft, and ships and boats. Machinery, other than electric, averaged £42,000,000 a month in July and August, which was £1,500,000 a month less than in the first half of the year; agricultural tractors and textile machinery accounted for most of the decline. Exports of road vehicles and aircraft, at under £31,000,000 a month in July and August, were £2,500,000 a month below the average for the first six months. Exports of ships and boats, which were very high in May and June, averaged £6,500,000 a month in July and August, which was about £1,000,000 below the average for the first half-year. Exports of electric machinery and apparatus were almost unchanged in July and August at a little over £18,000,000 a month. Exports of railway vehicles continued to increase and were £500,000 a month above the January–June average.

Overseas Constructional Work by British Firms

The Ministry of Works has recently published some details about constructional work overseas which has been undertaken by British firms. The value of such work done during the year ended March last, the Ministry says, was £87,000,000, compared with £70,000,000 in the preceding twelve months. Furthermore, the value of contracts obtained rose from £71,000,000 in 1954–55 to £108,000,000 in 1955–56. The work included in last year's total was carried out by fifty-five British building and civil engineering firms operating in sixty-two different countries.

The Ministry's survey goes on to explain that increases in labour and material costs vary considerably from country to country, and it is therefore extremely difficult to assess accurately the relative proportions of United Kingdom and local labour used in works of this kind. But even if an allowance of between 5 and 10 per cent is made for rises in cost, the Ministry feels that the volume of work done last year was significantly higher than that carried out in the preceding financial year. In addition, the substantial increase in the value of new constructional contracts obtained is an encouraging factor.

Most of the work done and the new contracts obtained last year were in the sterling area, though the proportion of work in that area was rather less than in 1954–55. The work done in non-sterling O.E.E.C. countries increased, and, although fewer contracts were obtained during the year, the work outstanding last March was about the same as it had been twelve months earlier. The share of constructional work done in the dollar area rose appreciably from less than 5 per cent in 1954–55 to over 20 per cent in 1955–56, the whole of this increase occurring in Canada. The Ministry's comment on the matter is that "this large increase is especially important and gratifying as further opportunities for British contractors in Canada can be expected."

Wage Restraint

Last week, the British Employers' Confederation issued a statement commenting on "points of considerable significance" which emerged from the recent Trades Union Congress debate on economic policy. This statement says that "neither the Government nor employers asked or expected that the T.U.C. would countenance a wage freeze and impose on their members any limitation of their right to make wage applications as opportunity offered." But, the Confederation asserts, it is lamentable that the T.U.C., in disclaiming any responsibility for the effects of wage increases, should adopt arguments which most of the delegates must know to be false, and ignore the fact that wage increases which are unaccompanied by increased efficiency must put up costs and thereby worsen our competitive position, and, at the same time, confer no benefits on the wage earners. The British Employers' Confederation goes on to express disappointment that the T.U.C.—despite the opposition of its general council—should have adopted, by a substantial majority, a resolution which conveyed "the totally unrealistic view that the time is now opportune to achieve the forty-hour week." It may well be, the Confederation comments, that these resolutions will have little effect on the final result of negotiations undertaken by the individual unions. They must, however, create a more difficult atmosphere for the conduct of negotiations.

"Aspirations of School Leavers"

The eleventh annual report of the Nuffield Foundation, which was published yesterday, shows that among the many different researches which the Foundation is assisting is a project in the department of psychology at Birkbeck College concerning the "long-term aspirations of people leaving school and starting work." This investigation was begun about three years ago when three groups of school leavers—from grammar, modern and technical schools—were selected for comparison. The report says that, as the inquiry got under way, it seemed less important to find out the extent to which young people plan ahead than the kinds of motives they have and their quality.

The investigation is now planned in three stages. In the first, the methods which were found promising in the preliminary study will be applied to a balanced sample of schools in London and elsewhere. The data obtained will be assembled to provide answers to such questions as: how do the selected groups differ in their motives; to what previous conditions can these differences be related, and how far are the differences predictive of the successes and satisfactions likely to be achieved in later years? In the second stage, the work will be extended to older students by "follow-up" procedures in universities, technical colleges, and in industry, and in the third stage the inquiry will be extended to cover international studies.

The object of this investigation is to find answers to some of the questions now being discussed in educational and industrial organisations. In particular, the report mentions such questions as whether the chief occupations are getting a fair share of recruits who have gone into the job for the right reasons; whether there is a lack of balance created by a drift to "white collar" occupations and the professions, and whether the reasons for any such drift are to be found in the home, in the schools, or elsewhere. Information will also be gathered on the extent of the drift from rural to urban occupations and from the north to the south of the country. It is believed that the results of this investigation will be of special interest and value both to educational and industrial administrators.

Industrial Designing

An international congress, organised by the Council of Industrial Design, was held recently in London. Its main theme was "The Management of Design," and the Council has now summarised the main conclusions reached by the discussion groups into which the congress was divided.

On the training of designers, the engineering industries represented at the congress expressed doubt as to whether art schools could provide sufficient technical and industrial background to meet the requirements. It was urged, in fact, that the true industrial designer should take a university engineering course which could be extended to cover the æsthetic aspects of design. It was also urged that industry could do more in the way of training its own designers, one practical suggestion being that the Council of Industrial Design, assisted by funds from industry, should administer travelling scholarships for young designers. One of the main functions of a designer, it was emphasised, was, by the exercise of his intuition and technical skill, to visualise the concrete form of products needed in the future. This capacity, the congress agreed, was all the more necessary because in many industries the process of tooling-up for a new design was a lengthy one, and the cost could not be recouped in some cases if the new model did not have a selling life of some years.

As to the implications for management, the opinion of the congress seemed to be that design policy should spring from the top level in a firm. Several firms stressed the importance of training in design appreciation for top management generally. Design policy, it was asserted, should be integrated into the work of all departments, for without it a "company handwriting" could not emerge.

National Management Conference

The British Institute of Management is to hold its annual conference at Harrogate from October 31st to November 2nd, the general subject for discussion being "Management, Profits and Living Standards." As is the custom at these conferences, the many aspects of the main theme will be studied in group discussions and summarised in a concluding plenary session.

The Institute believes it to be the task of management so to direct and control an organisation as to benefit not only its owners but its employees and, through supplying a good product at a reasonable price, its customers also. The term "profit," the Institute comments, has long ceased to mean merely the amount that is distributed as a return on capital investment. Profit is also gained when the resources of an organisation are built up and when the ratio of output to input is increased. It is only through the work of management along these lines that the national standard of living can be improved.

Postal Mechanisation Exhibition

A Postal Mechanisation Exhibition is to be held in Rome from October 29th to November 11th. It is being organised by the postal administrations of the six member countries of the European Coal and Steel Community, and Great Britain and Switzerland are also taking part. The British Post Office will include in its display specimens of mechanical and electrical devices now in regular use or under trial in post offices. Among these exhibits there will be a working specimen of a chain conveyor used for moving bags of mail from one part of a sorting office to another, and a pedestrian-controlled electric truck used for the delivery of parcels. There will also be shown devices used to train men employed on a new letter sorting machine which has been designed and built by the Post Office in its own laboratories.

Glockner-Kaprun Hydro-Electric Scheme

No. III—(*Concluded from page* 419, *September* 21*st*)

A major hydro-electric scheme in the Austrian Alps is described. It is a two-stage development with two seasonal reservoirs which permit about three-quarters of the net power output of 615 *million kWh annually to be generated in the winter. The total installed capacity is* 312*MW : pumping plant is also installed for additional peak load generation.*

THE constructional works at the sites of the various dams have generally followed established practice in the use of plant and in the constructional methods, apart from the various points of special interest already noted. The mountain topography was, of course, one of the main obstacles to be overcome. The illustrations of the dams (Figs. 1 and 10 *ante*) gave a good idea of the conditions and of the plant, and Fig. 12 shows the constructional plant at the upper site.

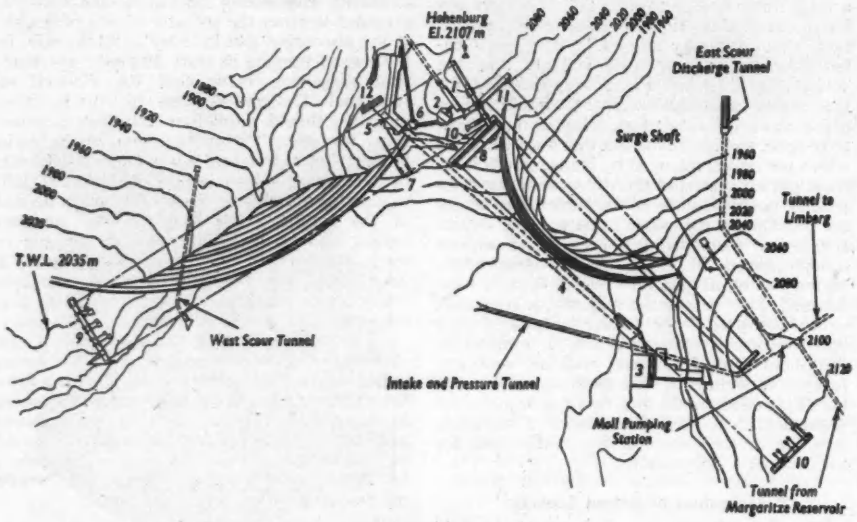


Fig. 12—Mooser and Drossen dams, showing permanent works and also the constructional plant layout for the two dams

Constructional plant at Mooser and Drossen dam sites

1—Terminal of cement ropeways from Kaprun railhead.
2—Cement silos.
3—Aggregate preparation plant (crushing, washing and screening, and sand separation).
4—Aggregate ropeways.
5—Aggregate silos.
6—Concrete batching and mixing station.
7—Turning area and tip for transferring concrete from dumpers to cableway skips, serving Mooser dam.
8—Turning area and tip for transferring concrete from dumpers to cableway skips, serving Drossen dam.
9—Cableways serving Mooser dam.
10—South cableways serving Drossen dam.
11—North cableways serving Drossen dam.
12—Workshops.

A single aggregate quarry was opened in the area of the Mooserboden reservoir, with the aggregate plant and storage close to Drossen dam. Aggregate for Limberg dam was carried down from here in the earlier stages of work. Limberg dam was built in a series of blocks, each extending the full width of the dam, and 20m to 30m in breadth, and separated by keyed gaps 1m in width.

A lift 2·25m in depth was added to each block at about weekly intervals, and the gap was concreted after twelve months. These gaps were, however, awkward to complete satisfactorily, and in the Mooser dam a chequer pattern of blocks, 15m to 30m square, was built, and the alternate low blocks built up after an appropriate interval. Finally, the joints of the dam were grouted. The richer facing concrete of this dam is 4m thick on the upstream face and 3m on the downstream, and is toothed into the hearting the "toothing" extending over a width of 1½m. On the Mooserboden site concrete was placed at an average rate of 2800 cubic metres daily, the maximum daily quantity being 4100 cubic metres.

Power Stations and Tunnels

Limberg power station is of reinforced concrete construction, with exceptionally massive structural members, as it has been designed to withstand avalanches. Winter access is given by a tunnel. The penstock from Wasserfallboden is a pressure shaft, excavated in the rock on the right bank. In spite of these necessary excavations works and the narrowness of the Limberg gorge, an underground power station was considered less attractive than the structure actually built at the toe of the dam. However, the Möll pumping station has, by contrast, been built underground.

The pressure shaft serving Limberg power station shows an interesting departure from normal practice, in that the concrete which must be packed behind the steel liner is in this case colloidal concrete (the method has, however, since been used on other Continental schemes). The dry, coarse aggregate was first placed behind the liner with a nominal thickness of 60cm, and then colloidal grout pumped in with a pressure reaching 7 to 11 atmospheres. A small drainage pipe is built close to the shaft, for the colloidal concrete was not considered to be completely impermeable. The design of this pressure shaft was not based on external hydraulic pressure on an empty shaft, as has been the case with some recent Swiss pressure shafts, nor were elaborate measures considered necessary to protect the steel from corrosion. Greater quantities of cement—350 kg and 400 kg per cubic metre respectively—were used for the reinforced concrete and the pumped concrete mixes then were used in the concrete for the dams.

The tunnelling works—the largest is the Möll tunnel—were extensive, but presented no special difficulties. The same is largely true of the earlier works at Kaprun, and of other works not specifically mentioned, such as the grouting programme at the various dams, and the side stream intakes on the Kaprun and Möll tunnels.

In the earlier works serving Kaprun power stations, one of the points of special interest was the use of a precast concrete tunnel lining, in places where bad rock was encountered. The lining was precast in segments, which were assembled into complete rings and then prestressed with steel cables, wound helically round each ring and tensioned by a machine not unlike those used for making prestressed concrete pipes.

The surge shaft at the end of the main stage tunnel is illustrated in Fig. 13. It consists of (*a*) a lower expansion chamber in the form of a horizontal tunnel (volume 1077 cubic metres) connected to the tunnel through a "throat" 1·82m in diameter ; (*b*) an inclined shaft, and (*c*) upper differential expansion chambers comprising a central tunnel and two side tunnels, each connected to the main one through a throat 0·8m in diameter (total volume of upper chambers 2479 cubic metres). The arrangements of the various tunnelling works at the two main reservoirs, and the water control gear, and so on, are indicated in Fig. 12.

Generating and Pumping Plant

The four Pelton wheel turbo-alternator sets at Kaprun power station, which form the main generating plant of the scheme, are representative of recent practice with this class of plant. Each set has two turbines overhung from two main bearings, with the alternator placed centrally. Each turbine has two jets in the larger 55MW sets. The net head varies between 780m and 870m. The sets generate at 550 r.p.m., 10kV, 50 c/s.

With these large sets, each turbine inlet is controlled by a spherical valve 850mm in diameter. The jet velocity reaches 130m per second, and the jet force about 26·5 tonnes. The two

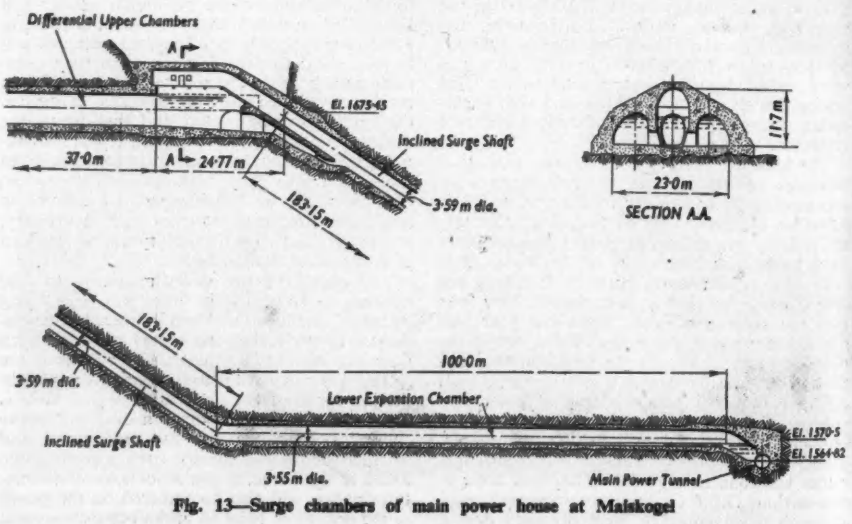


Fig. 13—Surge chambers of main power house at Maiskogel

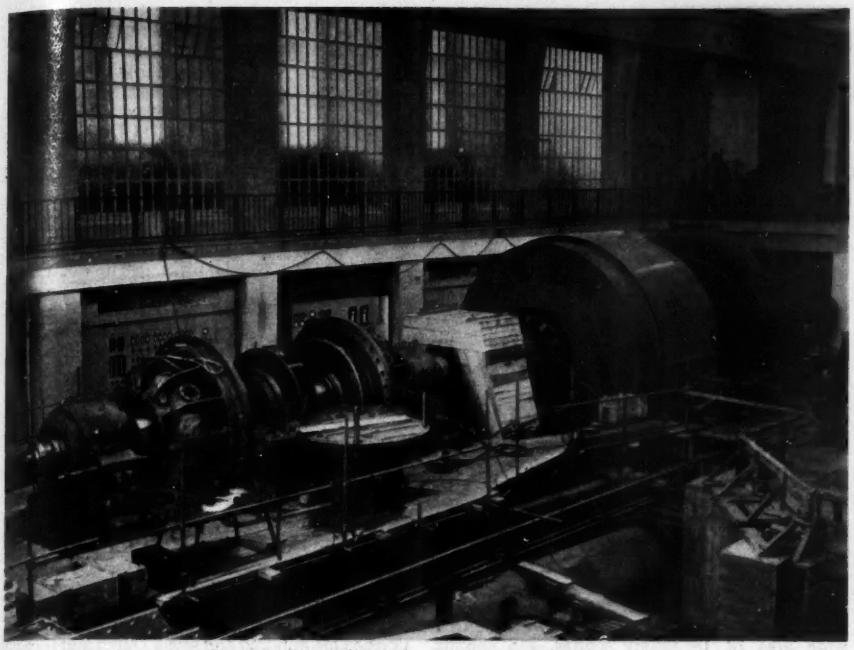


Fig. 14—Installation of horizontal-shaft-pumped storage generating set at Limberg power station. The Francis turbine and generator/motor are to the right and the two-stage impeller of the pump can be seen to the left of them

jets are controlled from a single oil servo-motor. There is, also, a braking injector. The makers state that the maximum efficiency measured on these turbines has been 91·2 per cent. Owing to the presence of very fine silt in the water, due to glacial erosion, all operating parts have been made readily accessible. Power from the Kaprun station is transformed to 110kV for transmission to the Tyrol, or 220kV or 110kV to Vienna. Power from Limberg arrives along a 110kV double line.

Fig. 15—The Möll underground pumping station. Access is by an inclined rail-mounted carriage (right background). The two pumps are single-stage centrifugal machines, each driven by a motor rated at 6700kW

260ft head). The 10kV transmission line from Limberg operates the motors directly, and the station, although always manned, is remotely controlled from Limberg. The diagram in Fig. 16, which shows the hydraulic connections for the upper stage works, clearly illustrates the mode of functioning of the Möll station, which permits (*a*) free flow from the Margaritze system into Mooserboden reservoir, when the latter is drawn down sufficiently ; (*b*) pumping from the Margaritze system into Mooserboden, or (*c*) direct flow from Margaritze to Limberg.

Pumping Sets at Limberg

The two main sets at Limberg power station are unusually powerful for pumped storage, but represent a class of installation which is likely to become increasingly common in the future. They each have a rated capacity of 56MW and consist of a horizontal-shaft alternator/motor, with a Francis turbine mounted on one side of it and a two-stage centrifugal pump on the other side. The set operates at 500 r.p.m. and the pump can deliver 11·7 to 16·6 cumecs, into Mooserboden reservoir, depending on the head, which varies between 320m and 420m for normal operating levels in the reservoirs. One of the special problems in the design of the pumps was the need to cater for this large range of operating heads.

Each set also includes a braking turbine and a mechanical clutch between the pump and the generator/motor. There are four modes of operation for the set, as follows : (*a*) Normal generation. The pump chambers are filled with water but the pump is stationary. (*b*) Phase

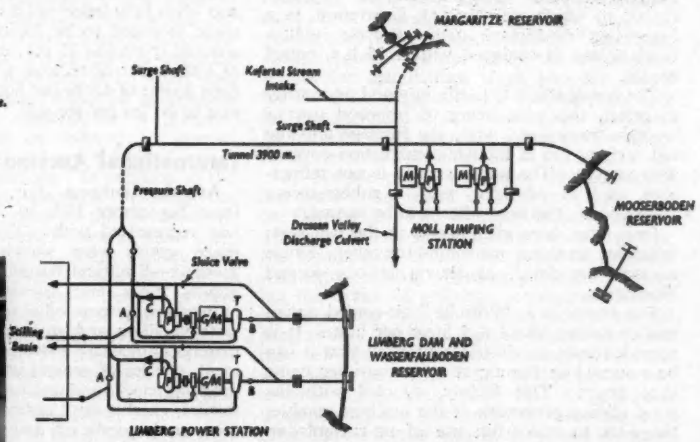


Fig. 16—Diagram of hydraulic connections of the upper stage of the Glockner-Kaprun scheme

There is more of interest in the upper stage plant, for considerable attention has been paid to developing pumping plant for hydro-electric schemes over the past few years, and so the installations of the upper scheme are far less standardised, particularly the pumping sets at Limberg. The machine rooms at Limberg and Möll are shown in Figs. 14 and 15 respectively.

The Möll underground station comprises a machine chamber 41m by 17m in size, containing two horizontal-shaft, single-stage centrifugal pumps, each driven by an asynchronous motor of 6700kW power output, operating at 10kV. The pumps operate at 500 r.p.m. and deliver a rated quantity of 20 cumecs against a head of 80m (i.e. about 700 cusecs against

correction. The generator gives reactive power and the main and braking turbines run empty ; the pump is unconnected in this mode, too. (*c*) Pumping. The main and braking turbines again run empty, the synchronous machine powers the pump at full load. (*d*) Pumping operation at part load, termed, literally, in Austria, " hydraulic short circuit." Both pump and turbine run filled in this mode.

The last-named mode of operation is one which has been used on several pumped storage schemes,† and results from the fact that, to obtain maximum efficiency, a pump must work at full load, or nearly so, whereas a turbine can run reasonably efficiently over a considerable range of loads. If the power available from the grid is insufficient to operate the pump at full load, part of the full rated discharge of the pump is by-passed back through the turbine, to generate power. Thus, the pump works at full load, though only a portion of the full load quantity is actually delivered. Fig. 16 illustrates the hydraulic connections installed to achieve this ; it may be recalled that the turbines at Limberg operate against a back-pressure and discharge into the Limberg reservoir. The outlets to the stilling basin are not used in normal operation. To start the turbines, the tail-race spherical valves " B " are first opened and then the entry

† E.g., the Etzel power station in Switzerland. See The Engineer, February 22 and 29, 1952, page 285 and page 320.

valves "A" are opened and the guide vanes adjusted. As long as these valves are open the pumps are filled, the pumps having shut-off valves only at "C" on the delivery side.

Control of all the upper stage works, including recording reservoir levels and so forth, is centred at Limberg. Control of the two pumping sets is completely automatic for all cases, including changing from one mode of operation to another. There are thus twenty different control programmes for the sets; any desired programme can be initiated by operating push-buttons and its completion is indicated by signal lights.

The change from operation with the turbine to that with the pump takes about five minutes. The braking turbine is first employed to bring the set to rest; this can be done in three minutes. Then the clutch is engaged (the clutch is a mechanical one and is engaged by operating a hydraulic cylinder) when the set is stationary. The main turbine is then operated to bring the set to synchronous speed, and finally the pump takes over. In the reverse process, however, the clutch can be disengaged at a speed of 40 per cent of the nominal speed.

The main manufacturers for the two sets at Limberg are the Austrian firm of Elin, for the generator/motors, and Escher-Wyss for the turbines and pumps.

Motorised Glider

A motorised, two-seater glider with a minimum endurance in the air of five hours, has been produced by Martin Neulen K.G., Parallelstrasse 115–117, Oberhausen (Rhld), German Federal Republic. The machine, the "Motorraab," of which we show an illustration, is a high-wing monoplane with tricycle undercarriage and is equipped with a 55 h.p. petrol engine.

The construction is partly in wood and partly in metal, the wing being of plywood over a wooden framework, while the fuselage and the tail surfaces are of tubular construction covered with canvas. The undercarriage is not retractable, and is provided with a rubber-spring suspension. The nose wheel can be steered.

One large door gives access to the two seats which are arranged one behind the other. Single controls are fitted, as shown in our second illustration.

The engine is a "Porsche" air-cooled design and consumes about 8·5 litres per hour. It is provided with an electric starter, so that it can be restarted in the air at any time after being shut down. This facility, coupled with the good gliding properties of the machine, enables the pilot to make full use of up-currents on slopes and of thermals to prolong the duration of flight substantially beyond its endurance on engine power alone. A propeller of 1·4m diameter is fitted. The petrol tank holds 48 litres.

Span, overall length and overall height are, respectively, 13·4m, 6·5m and 1·7m, the maximum width of the fuselage being 0·7m. With a wing area of 18 square metres, the specific wing loading is 23 kg per square metre, with one passenger, or 28 kg per square metre with two passengers.

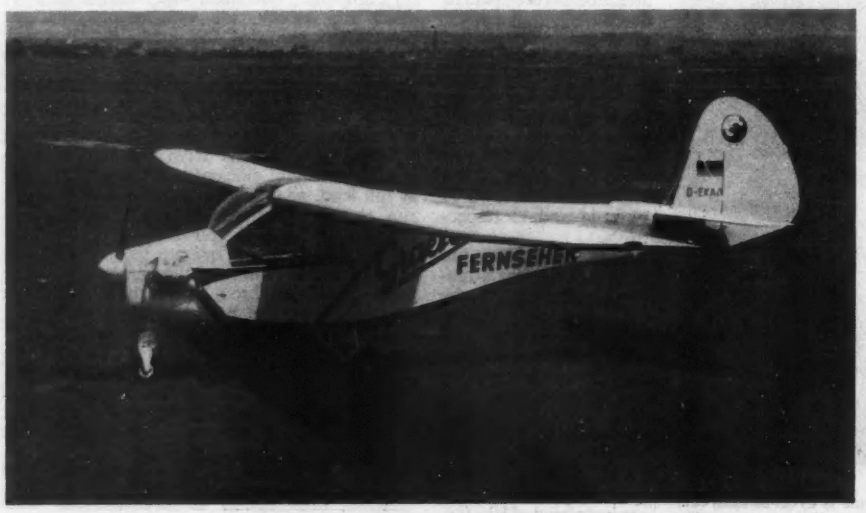
The aeroplane has an empty weight of 330 kg and when fully laden weighs 530 kg. Maximum speed is stated to be 130km per hour, with a cruising speed (on 75 per cent full engine speed) of 120km per hour, and a landing speed (with flaps down) of 45km per hour. Rate of climb is said to be 2m per second.

Instrument panel and controls of twin-seater motorised glider

International Autumn Fair at Utrecht

At the autumn fair, held at Utrecht from September 11th to 20th, Great Britain was represented with 123 exhibits. British-made goods were shown in the following groups:—Electrical household goods, lighting goods, radio and television sets, intercommunication systems, office machinery, accounting systems, filing and storage systems, packaging materials, medical instruments, hospital equipment, articles of general use, domestic chemical products, clocks and watches, smokers' requisites, textiles, perfumery, cosmetics, toilet articles, toys, sports goods, gift and souvenir articles.

The Utrecht Autumn Fair comprised 2000 exhibits and occupied an area of 33,000 square metres of exhibition space. Firms from twenty-two countries took part in this event. The electrical goods section, which was housed in the Julianahall and the Margriethall at the Croeselaan site, comprised 273 exhibits in the field of electrical household goods and lighting articles and radio and television sets. Besides 111 Dutch exhibits, 138 exhibits of foreign origin were to be seen, among which were sixty-five by German, twenty-four by English, and fourteen by American firms. The total area occupied by this exhibition was 7000 square metres, including a few stands on the open-air site. At the 1955 autumn fair this group occupied 4450 square metres and included ninety-six firms. Another important group was the medical section, which is represented every two years at the autumn fair. In this section were shown medical instruments and appliances, pharmaceutical preparations, and equipment for hospitals, including furniture and kitchen installations. One hundred and seven Dutch and foreign exhibits were shown on an area of 1687 square metres. Western Germany was represented with thirty-nine exhibits, the Netherlands with thirty-five and the U.S.A. with eleven exhibits. The efficiency section presents every year at the autumn fair a survey of office machinery, accounting systems, office furniture, filing and storage systems, intercommunication systems, stationery and packaging materials. This year it comprised 362 firms, occupying an area of 6320 square metres. Besides the products of 139 Dutch firms goods from 223 foreign factories were shown.



"Motoraab" motorised two-seater glider

German Plastics

The West German production of plastic sheets amounted in 1955 to a value of some 125 million D.M., an increase of 25 per cent on the previous year. During the same period the production of leatherette increased by about 15 per cent to a value of some 95,000,000 D.M. This upward trend may be attributed to the fact that the constantly improving quality of plastic sheets and leatherette enables them to be used for an increasing variety of purposes. The figures quoted do not include floor coverings in the form of P.V.C. strips, such floor coverings showed a specially high rise in turnover figures in 1955. Their popularity is increasing in comparison with other materials, particularly parquet flooring. The new products, which need hardly any care, have been extensively introduced into use in State-subsidised housing schemes.

Plastic sheets and leatherette are becoming increasingly popular abroad. In 1955, one-eighth of the total production of leatherette in the Federal Republic was exported. The average export of plastic sheets over the year was one-third of the entire production. With the exception of the countries of the Eastern *bloc*, practically all the countries of the world are being supplied.

Slabbing Mill Begins Operation

After one and a half year's work, Dortmund-Hörder Hütten-Union has completed its new slabbing mill which recently began its trials. The slabbing mill is placed between the ingot mill and the tandem plate mill, and in this way eases the load on the latter. During the last financial year, the plate mill produced about 530,000 tons of plate and medium sheet. The slabbing mill, which has now been installed at a cost of DM.85,000,000, will enable the output of plate to be increased further. This mill completes in broad outline the rebuilding of the sheet rolling mill, which has been in progress for the last six years. It will be recalled that before its removal under the post-war dismantling programme, the works possessed a plate mill for widths up to 5m.

Work of the U.S. Atomic Energy Commission

BY OUR AMERICAN EDITOR

No. I

THE twentieth bi-annual report to Congress of the U.S. Atomic Energy Commission (A.E.C.) covers the important step taken during the first half of 1956 toward the development of peaceful uses of atomic energy when President Eisenhower approved the recommendation of the Atomic Energy Commission to make available 40,000 kg of special nuclear materials as required for fuelling power and research reactors at home and abroad. In making the announcement, the President said : " This action demonstrates the confidence of the United States in the possibilities of developing nuclear power for civilian uses. It is an earnest of our faith that the atom can be made a powerful instrument for the promotion of world peace." The presidential statement pointed out that, as additional projects were undertaken by United States industry and by other nations, the Atomic Energy Commission would recommend that additional supplies of nuclear fuel be made available as became necessary. Of the uranium 235 allocated, 20,000 kg will be for domestic use, chiefly in power reactors, and 20,000 kg (in addition to 200 kg previously allocated) for research and power reactors in co-operating countries. The uranium will be distributed under conditions prescribed by the Commission.

Raw Materials

The production of uranium ore and concentrates from all sources in the free world continued to increase during the first half of 1956. The rise in domestic production was especially rapid, and the United States is now the free world's leading producer. The production of uranium ore and concentrates in the United States attained record levels during the reporting period. Three new mills were under construction and a number of concentrate proposals have been received which would involve the construction of additional mills. A new American uranium procurement programme will provide a guaranteed market for all uranium concentrates produced by domestic mills from domestic ores, subject to compliance with Commission specifications and also to a stipulation that the Commission reserves the right to limit its purchases from any one mining property or mining operation to 500 tons of U_3O_8 per year. Under the new programme the Commission established a base price for uranium concentrates, rather than for ores as formerly. The base price will be 8 dollars a pound for U_3O_8 contained in concentrates that comply with specifications and is applicable to the type of high-grade chemical concentrate now bought under negotiated unit price contracts with milling companies. If in excess of 500 tons U_3O_8 per year is purchased from any one mining property or mining operation, the price paid for the excess may be less than 8 dollars per pound of U_3O_8. As industrial demand for uranium develops, a gradual change from a Government-controlled to a commercial market is expected to take place, and producers will be able to sell to licensed domestic commercial users as well as to the Commission.

The number of uranium mines in production during the first six months of 1956 remained about the same as for the last six months of 1955, but the output from existing mines continued to increase sharply. Uranium ore production in the United States has reached nearly 3,000,000 short tons a year, and is expected to reach 5,000,000 or 6,000,000 tons a year. In 1948, only about 70,000 tons of ore was produced in the United States. Although no new uranium producing area was discovered during the last six months, several areas under development have been expanded. Ore production exceeded processing capacity, with ore being stockpiled at the sites of new mills. With the completion of new mills under construction or planned, these stockpiles will be reduced to normal operating inventories. All new mills and expansions are privately financed. In addition to the nine mills already in operation, including the one at Monticello, owned by the Commission, three are under construction, one at Tuba City, Arizona, one at Edgemont, South Dakota, and the other at Moab, Utah. Contracts for the purchase of production from a number of new plants are being negotiated. The new mills are being considered for such widely scattered areas as North-Western New Mexico, Southern and Eastern Utah, East-Central Colorado, Central Wyoming, and Eastern Washington. The total number of mills may be doubled by 1958. They range in size from 200 to more than 2000 tons daily ore capacity.

Private exploration has resulted in substantial increases in domestic ore reserves, particularly in the major uranium field in the Ambrosia Lake area, McKinley County, New Mexico, and in Central Wyoming. The potential reserves of the producing areas of the United States have been estimated at 30,000,000 tons of uranium ore. In addition, geological experts place the reserves of " indicated " and " inferred " ores at another 30,000,000 tons. There are large areas of the United States geologically favourable to uranium deposits that are yet to be explored. Government exploration activities, conducted by the Commission, the U.S. Geological Survey, and the Bureau of Mines continued to be concentrated on an evaluation of ore reserves and the results of private activity, on basic geologic studies of uranium ore deposits, and on the dissemination of information useful to private operators.

Production

The production of special nuclear materials continued to increase during the first half of 1956 as additional facilities were placed in operation. With the completion during the reporting period of the last units of the gaseous diffusion plant at Portsmouth, Ohio, and initial operation of a new chemical separations plant at Hanford, Washington, the Atomic Energy Commission now has in production all its additional facilities authorised in July, 1952.

Facilities now in production for turning out enriched uranium include three gaseous diffusion installations, at Oak Ridge, Tennessee, at Paducah, Kentucky, and at Portsmouth, Ohio. Facilities for the production of plutonium consist of eight graphite-moderated reactors at Hanford, and five heavy water-moderated reactors at Savannah River, South Carolina. To support these major production facilities, auxiliary plants are situated at the major sites. At reactor installations there also are plants for the final preparation of fuel elements and for the chemical separation of spent elements. At diffusion sites there are plants for manufacturing uranium hexafluoride feed material.

To provide private industries with additional information on which to base proposals, due on October 1, 1956, for manufacturing further quantities of uranium feed for production plants, the Commission arranged a series of seminars with representatives of private industry. Following this series of meetings, arrangements were made, at the request of firms active in this programme, for visits by individuals to " feed material " sites for further specialised discussions with local personnel. As an additional step toward doing away with the Government monopoly in the production of materials, and toward providing services for the atomic industry, the Commission invited private concerns to plan purchasing magnesium fluoride scrap generated at the feed materials plants. The Commission

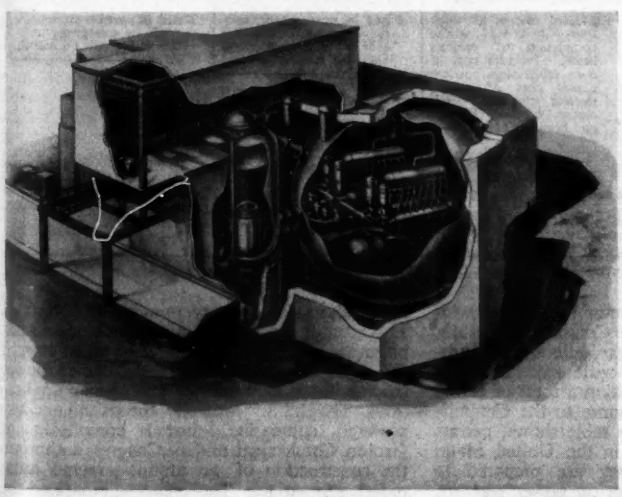


Fig. 1—Artist's impression of 140MW pressurised water reactor and steam generator under construction by Babcock and Wilcox for the Indian Point power station of the Consolidated Edison Company of New York

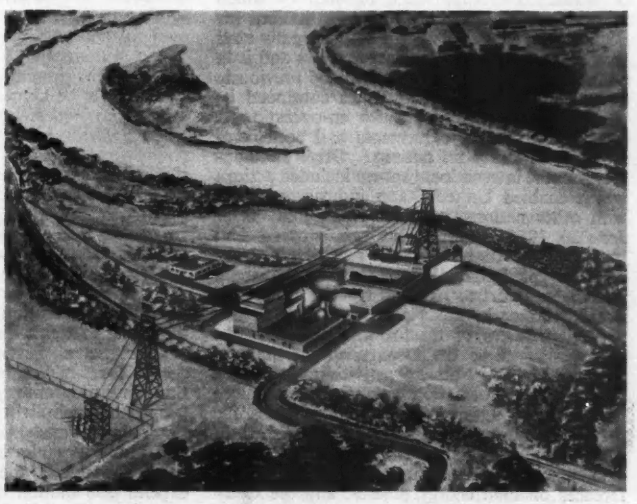


Fig. 2—Artist's impression of 60MW pressurised water reactor and power station under construction by Westinghouse for the A.E.C. and the Duquesne Light Company at Shippingport, Pennsylvania

estimated that 4000 to 8000 tons of scrap will be available annually. Interested firms were provided with scrap material and technical data for their calculations.

Military Application

Early in May, 1956, a full-scale series of tests began at the Eniwetok proving ground, in the Marshall Islands of the Pacific. This series, designated "Operation Redwing," incorporated further testing of devices leading toward development of defensive weapons, as well as testing of thermonuclear devices to verify the state of understanding of these weapons. In order to broaden public knowledge of the effects of thermonuclear weapons, and to provide non-governmental reporting of the conduct of a test at the Eniwetok proving ground, a selected group of fifteen newspaper representatives was invited to witness a detonation of a device with a yield in a range equivalent to millions of tons of T.N.T. Also included in this special group were seventeen observers selected by the Federal Civil Defence Administration. It is believed that this first-hand experience provided the observers, and through them the public, with information which will greatly enhance the civil defence effort. The meticulous safety precautions surrounding the tests, which included a danger area many times larger than the initial area used in the 1954 series, resulted in a thirteen-day postponement of the shot viewed by journalists and civil defence observers, due to unfavourable weather conditions. The explosive force of the detonation on May 20 of a device dropped from an aircraft was, as predicted, substantially lower than the largest yield of the 1954 series. The tests involved weapons generally smaller in yield than those tested during the 1954 series. The energy yield of the largest test fell substantially below that of the maximum 1954 test.

International Affairs

Outstanding among the events related to the international programme for the development of the peaceful atom was the agreement of twelve sponsoring countries of the United Nations, including the United States and the Soviet Union, on an acceptable basic charter for the establishment of an international atomic energy agency. Representatives of eighty-seven nations were invited to participate in a conference to consider this basic charter at United Nations headquarters in New York during September. This accomplishment grew out of the proposal for international co-operation to advance the peaceful uses of atomic energy which President Eisenhower made in his historic address before the United Nations General Assembly on December 8, 1953.

Another major development during the first half of 1956 was the allocation of 40,000 kg of contained uranium 235, one-half of which will be earmarked for use in foreign nations for peaceful purposes. This will be principally used for fuel in research and power reactors and is in addition to the 200 kg of uranium 235 previously allocated. As the United States continued its negotiations of agreements for co-operation, a total of thirty-eight agreements had been completed with thirty-six nations. Other developments in the international sphere included actions which enabled United States industry to work with other nations, with the result that, as of June 30, 1956, American business concerns had been selected to build seven reactors in other countries; pledged the United States to contribute financial support to research reactor projects in Brazil, Denmark, the Netherlands and Spain; resulted in sales of reactor materials abroad; gave assistance to the Department of State in various United Nations activities; facilitated exchanges of information with scientists of other nations; and assisted in developing plans for the Asian nuclear centre to be established in the Philippine Islands. United States scientists also participated in three international conferences on high energy physics, and the Commission broadened the opportunities for alien scientists to participate in non-classified research in Commission and certain contractor facilities. The Commission also assisted in United Nations plans to establish an international system for the collection of data on radioactive fall-out.

Reactor Development

The American programme for the development of nuclear reactors to generate electricity for civilian use went forward on a broad front during the last six months (Fig. 1). A fifth industrial combination announced its intention of building a power reactor without financial assistance from the Government. The Atomic Energy Commission signed its first contract under the private and public industry will build and operate. The electrical capacity of the civilian power projects to date totals a potential 1182MW.

During the reporting period, the Commission made further moves to bring private industry more strongly into the atomic energy programme. It signed long-range contracts for an expanded programme of commercial production of zirconium metal. The Commission proposed that private industries undertake chemical processing of spent fuel elements and manufacture additional reactor materials. The programme of develop-

Table I—*Civilian Atomic Power Development*

Type of reactor	Government's experimental programme	Power demonstration programme	Independent industrial programme
Pressurised water	Shippingport, Pa, Duquesne Light Company and Westinghouse Electric Corporation for A.E.C., 60,000kW—1957	Rowe, Mass, Yankee Atomic Electric Company, 134,000 kW—1960. University of Florida (Gainesville), 500kW—1959	Indian Point, N.Y., Consolidated Edison Company of N.Y., 140,000kW—1960.
Boiling water	Lemont, Ill, Experimental Boiling Water Reactor, Argonne National Laboratory, 5000kW—1957	Elk River, Minn, Rural Co-operative Power Association, 22,000kW—1960	Dresden, Ill, Nuclear Power Group (Commonwealth Edison Company and others) 180,000kW—1960. Livermore, Calif, General Electric Company and Pacific Gas and Electric Company, 3000kW—1957
Sodium cooled : Thermal	Santa Susana, Calif, Sodium Reactor Experiment, North American Aviation for A.E.C. and Southern California Edison Company, 7500kW—1957	Consumers Public Power District (Nebraska), 75,000kW—1959. Anchorage, Alaska, Chugach Electrical Association, Inc., and Nuclear Development Corporation of America, 10,000kW—1962	—
Fast	National Reactor Testing Station, Experimental Breeder Reactor No. 2, Argonne National Laboratory, 17,500 kW—1959 Los Alamos Scientific Laboratory, Molten Plutonium Reactor Experiment, no electricity—1959	Monroe, Mich, Power Reactor Development Company, Inc. (Detroit Edison Company and others), 100,000kW—1960	—
Fluidised : Aqueous homogeneous	Oak Ridge Laboratory, Homogeneous Reactor Experiment No. 2, no electricity—1956 Los Alamos Scientific Laboratory, Power Reactor Experiment Nos. 1 and 2, no electricity—1956	Hersey, Mich, Wolverine Electrical Co-operative, 10,000 kW—1959	Eastern Pa, Pennsylvania, Power and Light Company, 150,000kW—1962
Liquid metal	Liquid Metal Fuelled Reactor, The Babcock and Wilcox Company—1959	City of Orlando, Fla, 25,000–40,000kW—1961	—
Organic moderated	National Reactor Testing Station, Organic Moderated Reactor Experiment, North American Aviation for A.E.C., no electricity—1957	City of Piqua, Ohio, 12,500kW—1961	—
Gas-cooled	Gas-Cooled Reactor (contractor not selected)	City of Holyoke, Mass, 15,000 kW—1961	—
Unspecified	—	—	Florida (Florida Power Corporation) (Florida Power and Light Company) (Tampa Electric Company), 200,000 kW—1962
Costs (Dollars)	Government ... 236,000,000 Industry 20,000,000	Government ... 77,000,000 Industry 128,000,000	Government ... — Industry 210,000,000
	Estimated cost of all work from July 1, 1953, to the completion of projects listed. Includes cost of core fabrication but excludes cost of special nuclear materials. Excludes EBR-1, HRE-1, and Borax-1, 2 and 3	Based on proposals submitted to A.E.C. Excludes cost of core fabrication and of special nuclear materials	Based in part on statements made by sponsoring utilities and in part on A.E.C. estimates

	Kilowatts		Dollars
Total electrical capacity	1,182,000	Total estimated cost	671,000,000
Government's Experimental Programmes	90,000	Government	313,000,000
Power Demonstration Programme	419,000	Industry	358,000,000
Independent Industrial Programme	673,000		

Note.—The dates shown indicate the anticipated start of operation.

Power Demonstration Reactor Programme with the Yankee Atomic Electric Company of Boston, Massachusetts. Seven organisations made proposals for building small-scale reactors under this same programme, making a total of eleven proposals received in response to the Commission's invitations. As the table shows, private and public organisations in the United States have announced that they are prepared to expend 358 million dollars on power reactors, exceeding the 313 million dollars which the Government would invest—236 million dollars in its own experimental reactors, and 77,000,000 dollars in contributing to some reactors which

ing reactors for military power and for naval and aircraft propulsion also made significant progress. Preliminary steps were taken toward the eventual development of gas-cooled power reactors for special military and civilian applications. The U.S.S. "Seawolf" the second nuclear-powered submarine, neared completion at Groton, Connecticut, and the Congress authorised the construction of an atomic-powered radar picket submarine. The picket submarine—the largest submarine ever built by the Navy—will be the first powered by two reactors. Research and development activities on aircraft nuclear power plants progressed satisfactorily. The con-

struction of the Engineering Test Reactor (ETR) at the National Reactor Testing Station in Idaho proceeded on a top priority basis. Plans for a privately financed testing reactor were announced by the Westinghouse Electric Corporation.

In addition to the four large power reactors—each to produce between 140MW and 200MW of electricity—which private industry was previously reported as planning to build entirely with private funds, the Commission received notification in March 1956 that private concerns intend to build a fifth, smaller reactor. The General Electric Company and the Pacific Gas and Electric Company plan to construct and operate a boiling water reactor to help supply electricity for the San Francisco Bay area. The power station, which is to be situated at the new General Electric Company laboratory in the Livermore-Pleasanton area of Alameda County, California, is planned for completion during 1957 at a cost of between 3,000,000 and 4,000,000 dollars. Initially, it would have a maximum generating capacity of 3MW of electricity; ultimately of 10MW or more.

On June 6, 1956, the Commission signed its first contract with the Yankee Atomic Electric Company, an industrial group proposing to build a power reactor under the Power Demonstration Reactor Programme, by which the Commission agrees to make contributions to the project. During this same reporting period, the Commission received seven proposals to build small power reactors. They were submitted in response to its second invitation which specified reactors with capacities between 5MW and 40MW of electricity. The purpose of the Power Demonstration Reactor Programme is to demonstrate on a commercial basis the technical and economic feasibility of power reactors in a wide range of capacities and design concepts.

The contract with the Yankee Atomic Electric Company provides that the company will bear all construction costs, estimated at 34,500,000 dollars, of which 18,500,000 dollars is expected to be for the reactor. Research and development costs are estimated at 5,000,000 dollars. The Commission will perform research and development work up to 1,000,000 dollars in its own facilities, and will underwrite up to 4,000,000 dollars of this work in private facilities; research and development costs above 5,000,000 dollars will be borne by the company. The Commission agreed further to waive its normal charge for use of special nuclear material needed to fuel the reactor for a period beginning with the contract date, June 6, 1956, and ending five years after the date of issuance of a licence to operate the facility.

The contract provides that the company will report fully to the Commission on technical and economic information obtained in the development, design, construction and operation phases of the project. Patent rights in connection with work done with Commission assistance will be established by the Commission. The company will receive, as a minimum, a non-exclusive, irrevocable, royalty-free licence. In connection with inventions or discoveries made by the company or its employees without Government assistance, the company will grant the Commission a non-exclusive, irrevocable, royalty-free licence for governmental purposes. The contract also provides that spent fuel elements from the project will be processed in accordance with policies and prices in effect at the time processing is necessary. The company has selected the Westinghouse Electric Corporation to develop and design the project, and the Stone and Webster Company to construct the plant.

During the last six months, in addition to the work already being done in Government laboratories and under contract on five designs of power reactors, the Commission proceeded with contracts and experimental work to advance four additional concepts. A contract was signed for work on a reactor using an organic fluid as a moderator and coolant. Contract negotiations were begun for developing and constructing a reactor to use a liquid metal fuel. Outlines for research and development programmes were undertaken for reactors operating on a mixture of uranium and plutonium, and for gas-cooled reactors to operate in combination with gas turbine power plants.

Organic-Moderated Reactor Experiment

In March, 1956, the Commission signed a contract with Atomics International, a division of North American Aviation, Incorporated, to construct and operate an experimental reactor, moderated and cooled with an organic fluid, at the National Reactor Testing Station, in Idaho. The estimated cost of the initial phase of the Organic-Moderated Reactor Experiment (OMRE) is 1,800,000 dollars of which approximately 750,000 dollars will be borne by Atomics International. The experiment is designed to establish the technical feasibility of using the hydrocarbon diphenyl as a moderating and cooling material. The use of organic compounds such as diphenyl has several potential advantages: a low level of induced radioactivity, low corrosion of fuel elements, and a high boiling point, which would make possible systems operating at reasonably high temperature at low pressures. The experiment, which is carrying forward research previously done by North American Aviation, will simulate conditions of heat transfer, temperature, and coolant flow, which would exist in a practical power reactor. The OMRE will be designed to generate 5MW to 15MW of heat and will use fuel elements highly enriched in uranium 235. Construction will begin this year, and reactor operation is scheduled to take place early in 1957.

Liquid Metal Fuel Reactor Experiment

The Commission began negotiations with the Babcock and Wilcox Company for the development, design, fabrication and operation of a Liquid Metal Fuel Reactor Experiment (LMFRE). Babcock and Wilcox became a major research and development contractor for the Commission when its proposal was selected as the best of eleven submitted. The Union Carbide Nuclear Company will be a sub-contractor primarily in the chemical processing of fuel. The Liquid Metal Fuel Reactor Experiment will carry forward research work done by the Brookhaven National Laboratory on the concept of a reactor using uranium fuel dissolved in molten bismuth. The laboratory will continue to contribute to general development, while Babcock and Wilcox will concentrate on engineering aspects. The liquid metal fuel concept seems to offer considerable promise as an economic source of heat for central power station plants. In addition, its nuclear flexibility appears sufficiently great to permit its use in a thermal, intermediate, or fast, reactor in a variety of sizes. The present experiment will be designed to establish the basic technical feasibility of the concept, rather than to serve as a pilot plant demonstration of a particular liquid metal design concept.

Plutonium in Power Reactors

The Commission has requested the General Electric Company at the Hanford Works in Richland, Washington, to outline for the Commission's use a research and development programme covering the use of plutonium in power reactors. Combining plutonium with natural uranium as a reactor fuel would be of particular value to most foreign countries by freeing them from a dependence on importing uranium 235. Some domestic reactor designs also include plutonium as a fuel, although very little research and development work on its use has been done. A practical, low-cost plutonium fuel element is needed as well as basic data for the design of reactors using both uranium and plutonium. The development of uranium fuel elements and other advanced reactor technology will be additional objectives of this Hanford programme. The construction of a small experimental reactor is planned as the focal point of the programme, which would utilise the extensive development facilities at Hanford and the skills and experience of scientists and engineers who have worked on the Hanford production reactors.

Gas-Cooled Reactors

Gas-cooled reactors that use the heated gas to drive turbine power plants are considered a possible answer to the problem of economic power reactors of small size. Among the advantages of this concept may be simplicity of design, high efficiency, and independence from such environmental factors as a continuous supply of cooling water. The principal problem to be overcome in achieving an economically competitive reactor would be designing fuel elements that would have a reasonable life expectance at the high temperatures needed to obtain good thermal efficiency. During this reporting period, study contracts were negotiated with the Ford Instrument Company, a division of the Sperry Rand Corporation, and with the Studebaker-Packard Corporation, to provide a better understanding of the potential economics of this concept, and to delineate the research and development remaining to be accomplished.

Pressurised Water Reactor

During the first six months of 1956, the construction of the Pressurised Water Reactor (PWR) at Shippingport, Pennsylvania, continued (Fig. 2). The Dravo Corporation of Pittsburgh, Pennsylvania, was selected by the Westinghouse Electric Corporation as the sub-contractor for installing the reactor. The construction of the reactor vessel, to contain the core of uranium fuel, continued in the Chattanooga shops of Combustion Engineering, Incorporated. The heat exchangers, being built by the Babcock and Wilcox Company and by the Foster-Wheeler Corporation, are approaching completion. The Duquesne Light Company of Pittsburgh is building the conventional portion of the plant and will operate the entire station. The PWR plant will be the first large nuclear power generating station in the United States, with a capacity of at least 60MW of electricity. The Shippingport plant, estimated to be completed in 1957, is not expected to produce economic power, but rather to provide information that can be obtained only from the construction and operation of a prototype plant. The pressurised water concept has been developed further than any other in the power field. Experience with the Hanford reactors, the Materials Testing Reactor, and the Submarine Thermal Reactor developed technical knowledge which is being applied in the PWR scheme.

Boiling Water Reactor Programme

The Boiling Reactor Experiment No. 3 (Borax–3) was shut down in April after operating at the National Reactor Testing Station for about six months at design temperature and at power levels up to that necessary to produce about 2MW of electricity. A second core of oxide fuel elements is being fabricated and will be used in continuing the experiment as Borax–4. This design of reactor differs from the pressurised water reactor in that steam generation is allowed to take place in the reactor core itself. Borax–3, which is one of the series of similar plants designed by the Argonne National Laboratory, became critical on June 9, 1955. It was the first reactor to be used in this country to supply experimentally the power and light for an entire city. The phase in the boiling water reactor programme following the Borax–3 and Borax–4 experiments will be the construction and operation of the Experimental Boiling Water Reactor (EBWR) at the Argonne National Laboratory. The facility is expected to be generating power early in 1957.

In addition to eliminating an external heat exchanger, a boiling water reactor has the advantage that the steam pressure and temperature can be as high as those in the reactor vessel, thus improving the total thermal efficiency of the plant. Conversely, a cheaper reactor vessel can be designed for a given steam pressure. One important aspect of this design is that an increase in demand leads to a lower reactor pressure, an increase in the steam volume, and a reduction in the reactivity and power level. The reactor thus has good nuclear stability. This feature, although contributing to the safety of the reactor, tends to lower, rather than to increase power to meet rising demand.

(*To be continued*)

Personal and Business

Appointments

MR. AIREY NEAVE, M.P., has joined John Thompson, Ltd., Wolverhampton, as legal adviser.

MR. S. F. PERRY has been appointed general works manager of F. G. Miles, Ltd., Shoreham Airport, Sussex.

MR. F. G. PHIPPS has been appointed a director of Davy and United Roll Foundry, Ltd., Middlesbrough.

MR. J. ROY, A.M.I.Mech.E., has been appointed chief engineer of Cowans, Sheldon and Co., Ltd., Carlisle.

MR. J. N. WILSON and MR. R. S. FORD have joined the board of C. R. Averill, Ltd., Alyn Mills, Caergwrle, Wrexham.

MR. BRYAN DONKIN, M.I.E.E., has accepted the invitation to become president for 1956–57 of the Junior Institution of Engineers.

NORRIS, HENTY AND GARDNERS, Ltd., Patricroft, Manchester, states that Mr. D. G. Houghton, sales manager, has been appointed a director.

THOS. STOREY (ENGINEERS), Ltd., Brinksway, Stockport, states that Mr. Frank Curbishley, works manager, has been appointed a director.

HEAD WRIGHTSON AND CO., Ltd., has announced the appointment of Mr. G. P. Davidson as head of its nuclear power plant activities.

MR. G. GORDON MUSTED has been appointed West Midlands technical representative of Courtburn Positioners, Ltd., Kempston Hardwick, Bedford.

MR. K. R. LAURENCE has been appointed a director of Winston Electronics, Ltd., Shepperton, Middlesex. He has been general manager of the company since 1953.

MR. G. B. R. FEILDEN, engineering director of Ruston and Hornsby, Ltd., has been appointed to the British Transport Commission's research advisory council.

CATERPILLAR TRACTOR Company, Ltd., Desford, Leicester, states that Mr. T. Harold Edwards has been appointed chief buyer, and Mr. T. V. J. Armstrong, merchandise manager.

MR. LEONARD LEE, M.I.Mech.E., has been appointed general manager of Alldays and Onions, Ltd., Birmingham. He was formerly chief engineer of James Howden and Co., Ltd.

MR. C. W. HODGSON, A.M.I.E.E., has been appointed chief engineer, thermal power plants, of Ewbank and Partners (Canada), Ltd., Toronto. He was formerly generation engineer (construction), East Midlands division of the Central Electricity Authority.

NORTHERN ALUMINIUM COMPANY, Ltd., has announced the following appointments :—Mr. D. W. Taylor, manager of Birmingham area sales office ; Mr. D. A. Pinn, export sales manager ; Mr. H. M. Louch, manager of Bristol area office ; Mr. H. Q. Lievesley, manager Leeds area office ; Mr. D. L. Roper, manager of Southampton region office.

THE BRITISH INTERNAL COMBUSTION ENGINE RESEARCH ASSOCIATION announces the re-election of Viscount Falmouth as president. Sir Harold Roxbee Cox, Dr. S. F. Dorey, Brigadier H. P. Drayson, and Vice-Admiral (E.) Sir Frank Mason, have been re-elected vice-presidents, and Professor O. A. Saunders has accepted an invitation to become a vice-president. Mr. H. N. G. Allen and Mr. L. W. Robson have been elected to the council, and Mr. G. W. Bone has been elected chairman of the council.

Business Announcements

SIR HARRY METHVEN has retired from part-time membership of the British Transport Commission.

MR. C. R. D. TUCKEY, general sales manager of British Timken, Ltd., has left this country for a world tour.

FLEXIBOX, Ltd., Trafford Park, Manchester, is shortly to occupy an additional factory at Ballymena, Northern Ireland.

R. A. LISTER (MARINE SALES), Ltd., Dursley, Glos, states that from October 1st it will be known as Lister Blackstone Marine, Ltd.

GEORGE ANGUS AND CO., Ltd., states that the address of its oil seal division is now Coast Road, Wallsend, Northumberland (telephone, Wallsend 64551).

THERMOTANK, Ltd., has formed a new company entitled Thermotank Plastic Engineering, Ltd., for the production of glass fibre reinforced plastics rods, bars, tubes and sheets. The company is operating at Chapelhall Works, near Glasgow.

THE LOCOMOTIVE AND ALLIED MANUFACTURERS' ASSOCIATION has changed its address to Locomotive House, Buckingham Gate, London, S.W.1 (telephone, Victoria 1426).

JOHNSON, MATTHEY AND CO., Ltd., has formed an associated company in France, entitled Etablissements Johnson, Matthey et Cie, S.A. Its offices are at 76, Boulevard Haussmann, Paris.

MIDLAND SILICONES, Ltd., states that Electrical Trades Supply, Ltd., Loveday Street, Birmingham, 4, has been added to the list of distributors of its electrical insulating compound " MS 4."

ARMSTRONG WHITWORTH (METAL INDUSTRIES), Ltd., and JARROW METAL INDUSTRIES, Ltd., have moved their Sheffield office to Whiteleys Chambers, Surrey Street, Sheffield, 1 (telephone, Sheffield 24629).

THE ENGLISH STEEL CORPORATION, Ltd., has announced the retirement, from executive duties and from the board, of Mr. Basil Gray. Mr. Gray has been a director since 1946 ; he began his professional career with Vickers, Ltd., Sheffield, in 1910.

UNIVERSAL LAUNCHES, Ltd., announces that it will shortly transfer its business from Bideford to Sarisbury Green on the River Hamble, near Southampton, in premises formerly occupied by Solent Shipyards, Ltd., and will in future operate under the name of Universal Shipyards (Solent), Ltd.

RICHARDSONS WESTGARTH (HARTLEPOOL), Ltd., states that it is now manufacturing and marketing boilers covering evaporations from 3000 lb to 18,000 lb per hour, supplied as complete steam raising units with all ancillary equipment or as bare boilers with steam and water mountings only.

THE BRITISH OXYGEN COMPANY, Ltd., has formed a new company entitled British Oxygen Research and Development, Ltd. Dr. P. H. Sykes is the chairman, and Dr. Norman Booth, managing director. This new company is taking over the work of British Oxygen's research and development centre at Morden, Surrey.

RANSOME AND MARLES BEARING COMPANY, Ltd., Newark-on-Trent, has opened a new branch office at 58–60, Paradise Street, Liverpool, 1 (telephone, Royal 7331). Mr. E. L. Paton is the manager. The telephone numbers of the company's branch at 4, Great Central Street, Leicester, have been changed to Leicester 24739 and 24730.

SIR EDWIN PLOWDEN, chairman of the United Kingdom Atomic Energy Authority, and Sir John Cockcroft, director of the Atomic Energy Research Establishment at Harwell, are attending a meeting in the U.S.A. on the economic aspects of nuclear energy. It is part of the programme arranged for this year's meeting of the International Bank.

Contracts

THE HYDRO-ELECTRIC POWER COMMISSION, Ontario, Canada, has ordered from C. A. Parsons and Co., Ltd., Heaton Works, Newcastle upon Tyne, two more 200MW turbo-generators, to be installed in the Richard L. Hearn generating station, Toronto, bringing its output to 1000MW.

C. A. PARSONS AND CO., Ltd., Heaton Works, Newcastle upon Tyne, has received an order for two 66MW turbo-generators, complete with surface condensing plant, from the Manitoba Hydro-Electric Board, Winnipeg, Canada. The turbines will operate with steam at a pressure of 850 lb per square inch gauge at the stop valve and a temperature of 900 deg. Fah. The generators will be of the hydrogen-cooled type, generating at 13,800V. The machines are to be installed in a new power station which will be situated about 24 miles north of Winnipeg on a site opposite Selkirk, on the Red River. The total value of the contract is put at £1,308,000.

Miscellanea

MACHINE TOOL DEMONSTRATION AT MANCHESTER.—To mark the opening of new offices and a showroom at Warwick Road South, Old Trafford, Manchester, Alfred Herbert, Ltd., will hold a machine tool demonstration from October 2nd to October 13th next. In addition to machine tools of some fifty types, there will also be on view a selection of measuring equipment and a wide range of small tools.

EXHIBITION OF SAILS AND RIGGING.—At the Scottish Council Offices, 2/4a, King Street, St. James's, London, a representative exhibition of rigging and sails for the " Mayflower II " was opened on September 18th and will remain open for a month. The ropes have been manufactured by the Gourock Ropework Company, Ltd., which was established in 1736, and the flax sailcloth is the product of Francis Webster and Sons, Ltd., Arbroath, which was founded in 1795.

KEROSENE BURNING APPLIANCES.—This week an exhibition of kerosene burning appliances was staged by the Shell Petroleum Company, Ltd., and demonstrated the wide application of kerosene as a source of heat and light. Some sixty different items were on view, covering various industrial and agricultural equipment, several forms of lamps and space heaters, domestic water and storage heaters, cooking appliances and refrigerators, and even a kerosene-operated radio set.

MINIATURE CIRCUIT BREAKER.—British Central Electrical Company, Ltd., 6 and 8, Rosebery Avenue, London, E.C.1, has introduced a series of miniature circuit breakers with ratings from 0·1A to 22A in 0·1A steps. The breakers are suitable for 400V a.c. or 150V d.c., and are only 2 $\frac{1}{16}$in by 1$\frac{1}{4}$in by $\frac{1}{2}$in in size. The accuracy of rupturing is 0·1A, and the device has withstood without damage nearly 80,000 operations. They can be supplied to trip on the slightest sustained overload, any heavy overload, or under short circuit, so that they can be used to protect motors which take an instantaneous overload at starting. The quick break switch is controlled by a bi-metal strip, and the main contact does not take part in the make and break, in order to avoid pitting or burning. Additional contacts for a supervisory circuit can be provided and a manual trip button is optional. Resetting is manual, but the breaker cannot be held in a faulty circuit.

FLYWHEEL MAGNETO TESTING.—The recent rapid spread of two-stroke engines has called for equipment to test the specialised electrical ancillaries associated with them, and in developing their " Magmaster " equipment Crypton Equipment, Ltd., Bridgwater, Somerset, made provision for testing over 100 different flywheel magnetos. The test bench has three divisions : the centre drive unit mounts the magneto or other device and drives it with the required angular velocity, and includes variable spark gaps and an automatic advance test gap ; the ignition test unit is mounted on the power drive, but carries out checks on coils, condensers and other components independently, having a vibrator pulse generator ; and the electrical test unit, correspondingly mounted, tests a.c. or d.c. generators and other components either on the bench or on the engine. Either or both of the latter can be attached to the centre unit. The insulation and continuity test facilities include a source of high tension current, and enclosed waterproof accessories can be accommodated.

APPRENTICE TRAINING CENTRE.—A comprehensive new training centre for apprentices has been inaugurated at the Erdington, Birmingham, works of Birlec Ltd., the furnace manufacturers. About sixty apprentices are employed by this firm and the new centre has a staff of four full-time instructors. The centre covers an area of about 10,000 square feet and it incorporates a well-equipped workshop, a drawing-office and a lecture room. Under the firm's apprenticeship scheme two main courses are provided for technical and craft apprentices, each of five years' duration. All apprentices spend their first year on preliminary courses in the centre to find the direction in which their abilities lie, and to give them an insight into the fundamentals of engineering with particular reference to those branches with which the firm is concerned. After this probationary period, apprentice indentures are signed and training is then continued in appropriate departments for the remainder of the five-year period, selected apprentices returning to the training centre for advanced instruction at an intermediate stage.

MOBILE SCHOOL FOR RAILWAY MAINTENANCE STAFF.—The extension of electrification on the Southern Region, which forms part of the British Railways' modernisation scheme, will necessitate the setting up of new depots for the servicing and maintenance of electric rolling stock at various points. For the purpose of training new staff to man these depots and keep existing staff abreast of new techniques and the new types of equipment the Southern Region has introduced a three-coach instructional train. This train will travel to the various depots concerned to avoid the large amount of travelling which would otherwise be involved if the staff were required to attend at a central instructional school. The instructional train consists of three converted passenger coaches in which the original electrical equipment has been retained so that the coaches form a complete electric train which is self propelled within the electrified area. The coaches have been fitted with working specimens of all the various items and types of equipment which a depot staff will be required to maintain. Panel diagrams used to show the working of the electrical circuits incorporate arrangements to permit the instructor to affect circuit faults so that the trainees may learn to diagnose and correct faulty operation of the equipment.

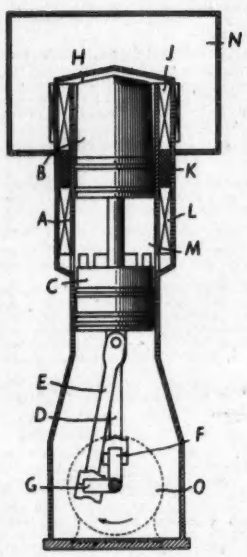
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

HOT-GAS ENGINES AND REFRIGERATING PLANTS

756,732. September 11, 1952.—THERMAL REGENERATORS, N. V. Philips' Gloeilampenfabrieken, Emmasingel 29, Eindhoven, Holland.

The invention relates to thermal regenerators which may be used in hot-gas reciprocating engines and refrigerating apparatus and heat pumps operating according to the reversed hot-gas reciprocating engine principle. The invention concerns a thermal regenerator comprising a filling mass composed of lengths of wire with a hydraulic diameter or four times the surface of the wire divided by the circumference of a right cross section of the wire at any point smaller than 50 microns, and the wire is formed with a large number of small curls. Adjacent curls in the direction of length of the wire are disposed in approximately the same plane, substantially perpendicularly to the general directions of fluid flow, and the wires follow a random path in the regenerator space. The regenerator is particularly suitable for use in refrigerators in which it is required to satisfy stringent requirements. The refrigerator shown in the drawing comprises a cylinder *A* in which a



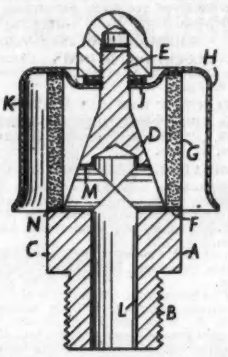
No. 756,732

displacer *B* and a piston *C* reciprocate with a substantially constant phase-difference, the displacer leading in phase with respect to the piston. The displacer and the piston are each connected through connecting rods *D* and *E* to a crank *F* and *G* of the crankshaft. The chamber *H* above the displacer *B* is the freezing chamber and communicates through a freezer *J*, a regenerator *K* and a cooler *L* with the space *M* between the displacer and the piston, being the cooled space. Through the wall of the freezer *J* and the wall of the freezing chamber *H* thermal energy is supplied to the working medium which follows a closed thermodynamic cycle in the apparatus. Thermal energy is withdrawn from the space *N* surrounding the freezer and from the freezing chamber *H*, so that this chamber attains a low temperature. In the cooler *L* thermal energy is removed from the working medium, for example, to water or to the open air. The refrigerating apparatus is driven by an electric motor *O* or a petrol or diesel engine. The regenerator *K* is formed in accordance with the invention and two further embodiments and a method of construction are also described in the specification. —*September* 5, 1956.

SIEVES AND FILTERS

756,336. January 12, 1953.—AIR FILTERS, Perry Combustion Accessories, Ltd., The Wharf, Clapham Street, Leamington Spa. (*Inventor: William Murray.*)

The object of the invention is to provide an air filter unit of simple and strong construction to be connected to an air space, such as the crank case of an internal combustion engine, to form an air intake, and is constructed so that the component parts of the unit may be readily disassembled as by simply releasing a clamping nut for cleaning. As will be seen from the drawing, the air filter unit comprises a body *A* having a threaded end portion *B* by which it is screwed into the crank case of an internal combustion engine, and a nut portion *C*. The upper portion of the body is tapered upwardly at *D* and terminates in a screw-threaded shank *E*. Between the nut and the tapered portion there is formed an annular shoulder *F* to seat one end of a hollow cylindrical filter element *G* of sintered bronze, the shoulder serving to position the filter element concentrically in the body. A cup-shaped cowl *H* seats in an inverted position upon the other end of the filter element *G* and the base of the cup is dished as at *J* to engage within the other end of the element



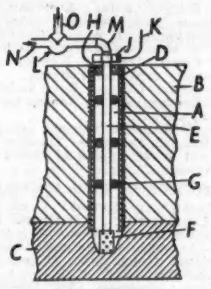
No. 756,336

G and to position the cowl concentrically. The threaded shank of the body extends through the aperture to receive a serrated lock washer combined with a synthetic rubber washer, and a dome nut. By tightening the dome nut, the filter element is firmly gripped between the base of the cowl and the annular shoulder and by removing the nut and the cowl, the filter element can readily be removed for cleaning or replacement. A central bore *L* in the body intersects a transverse bore *M* across the body, providing an air passage by which the screw threaded end of the body communicates with the interior of the filter element *G*. The filter element has bonded to it at each end a sealing ring *N* of synthetic rubber. When the filter unit is fitted to the crank case of an internal combustion engine air expelled from the crank case will pass through the bores and the filter element *G* while the filter also permits air to be drawn into the crank case. In this manner, the filter unit acts as an air filter and a "breather" for the crank case.—*September* 5, 1956.

MINING ENGINEERING

756,582. January 15, 1954.—THE UNDERGROUND GASIFICATION OF COAL, The Minister of Fuel and Power, London. (*Inventor: Philip Edward Montagnon.*)

This invention relates to the underground gasification of coal. The main objects of the invention are to reduce the loss of electrical energy due to the presence of water, and to lessen the risk of electrical leakage between those parts of the electrodes or other electrical conductors extending within the boreholes and the walls of the boreholes themselves. In the drawing is shown a borehole *A* extending



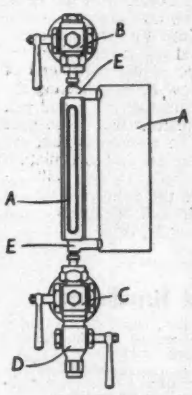
No. 756,582

through an overburden *B* and into a coal seam *C*. Each borehole is lined at *D* with a suitable pressure-resistant and waterproof material. An electrical conductor *E* central in the borehole is spaced from the lining. It comprises a tube capable of carrying the current required and also able to withstand the temperature resulting from the operation of the process as well as the corrosive effects of the gases evolved from the coal during the passage of the current. The conductor tube is tipped at its lower end with a length of perforated stainless steel tube *F*. This may either rest in a hole drilled in the coal seam or may be surrounded by closely packed granules of graphite or other conducting material in granular form, to ensure good electrical contact with the coal seam. The conductor tube may be insulated from the lining by heavy insulating rings *G*, of high-temperature resistant glass or silica which serve also to position the tube centrally with respect to the borehole. At the top the conductor tube *E* extends through a gland in a flange *H* of electrically insulating material firmly attached to the borehole lining *D*. At a point where it projects from the borehole, the conductor tube carries a terminal clamp *J*, by which it is connected to an electrical supply cable *K*. Between the part of the conductor tube engaged by the clamp and a two-way valve *L* the tube connects with a conduit *M* formed of electrically insulating material. The valve *L* puts the conduit *M* in communication with one of two pipes *N* and *O*, of which the former is connected to a source of pressure air, or other gas, while the latter communicates with an exhauster pump. Modified arrangements are also shown in the specification.—*September* 5, 1956.

STEAM GENERATORS

756,032. January 7, 1953.—LIQUID LEVEL INDICATING DEVICES FOR STEAM BOILERS, The Malone Instrument Company, Ltd., The West Chirton Industrial Estate, North Shields, Northumberland, and Ray Malone, of the company's address.

The invention relates to a liquid level indicating device for a marine boiler provided with conventional gauge-glass cocks, and has for an object to provide an improved form of liquid level indicating device with a stabilising vessel. In one application of the invention the stabilising vessel is connected, in parallel with the normal gauge glass, to the boiler through the usual upper and lower cocks. With a normal cock aperture of ¼in diameter, it can be calculated that by making the stabilising vessel 4in in diameter, the vertical fluctuation of level in the glass is limited to a total range of approximately 3in when a ship is pitching with a pitch cycle of 10 seconds and the mean head of water above the lower cock is 0·4ft. With only a 3in total fluctuation of level in the gauge glass a mean reading is easily taken and will indicate approximately the water level in the boiler. Referring to the drawing, there is shown a normal prismatic glass water gauge provided with the usual prismatic indicating glass. The normal straight connection of each end of the indicating glass to the respective connecting cock is replaced by a "T"-union connected to the end of the corresponding cock and also to one end of an elongated cylindrical ballast or stabilising vessel *A*, the vessel being connected in parallel with the gauge glass. The cross-sectional area of the vessel is large compared with that of the passage in the lower "T"-union and water flowing into the vessel from the boiler or from the vessel into the boiler when the level of water in the boiler is fluctuating is restricted by the passage in the "T"-union. Thus, the fluctuation of level in the vessel and, therefore, in the indicating glass, is considerably reduced compared with that of the water in the boiler so that the indicating glass is never empty or completely full and a mean reading of the maximum and minimum values will represent the level of water in the boiler. Modified types of gauges are also described in the specification. —*August* 29, 1956.

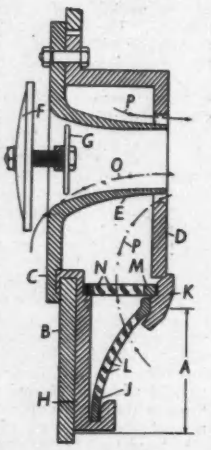


No. 756,032

755,858. November 16, 1953.—FURNACES, Leon Gerald Leanse, 82–90, Seymour Place, London, W.1.

The invention relates to the construction of furnaces and more particularly to an arrangement for preheating a supply of secondary air to a boiler or like furnace. As shown in the drawing, the furnace has adjacent the fire-bed *A* a fire-door opening in one of the vertical side walls *B*. The fire-door comprises an outer substantially annular member *C* and an inner member in the form of a cranked plate *D* secured to the furnace side of the outer member. The central portion of the outer fire-door member extends inwards and constitutes a nozzle *E* through which a stream of secondary air may be admitted into the furnace. The inner fire-door member *D* has a flange secured against the top of the outer member and an annular front portion encircling the outlet end of the nozzle. For controlling the amount of air passing through the nozzle a regulator is provided at the inlet end of the nozzle. This regulator comprises a pair of spaced discs *F* and *G* secured to a screw which is threaded through a boss in the outer fire-door member. The smaller of the

two discs is movable within the nozzle and the other disc is movable towards and away from the surface of the outer fire-door member upon rotation of the screw. Directly below the fire-door and level with the fire-bed of the furnace is the grate-box. The front wall of the grate-box is constituted by a plate *H* which rests against the front wall *B* of the furnace, the top part being hooked over the fire-door opening and the bottom part turned inwards and upwards to provide a locating channel for the bottom edge of a grid frame *J*. This frame slopes towards the fire-bed, the upper end resting on a buttress *K* within the furnace. The frame supports a series of parallel horizontal loose grid-bars *L* between which the combustion gases from the fire-bed are caused to flow in an upward direction. The grid-bars themselves lie in a slight curve and are of elongated cross-section in the direction of gas flow. The upper limit of the grate-box is defined by a horizontal grid frame *M* having similar grid-bars *N* and being supported at one side edge by a shoulder on the vertical furnace plate *H* and along its opposite side edge by a shoulder on the buttress member *K*. The effect of the construction is that upon opening the air regulator the rush of air shown by arrow *O* through the nozzle *E* into the furnace creates a region of low pressure in the annular space around the nozzle with the result that a proportion of the combustion gases are drawn up through the grate-box into the annular space surrounding the nozzle *E* and are injected into the secondary air stream in front of the outlet end of the nozzle, as shown by arrow *P*, thus heating the secondary air in producing a mixture of air and gas. By adjustment of the regulator, the volume of secondary air admitted can be adjusted within the widest required limits and the air and gas mixture temperature adjusted to a value which will be dependent upon the ratio of the temperatures and of the quantities of the air and the combustion gases which are mixed.—*August* 29, 1956.



No. 755,858

Catalogues and Brochures

RICHARDSON SCALE COMPANY, Ltd., 40/42, George Street, Nottingham.—Leaflet No. 5301, describing and illustrating a "G17" semi-automatic gross bagging machine.

DALLOW LAMBERT AND CO., Ltd., Thurmaston, Leicester.—Descriptive leaflet giving details of this firm's dust control equipment, designed for collecting cast iron dust and swarf.

ADDISON ELECTRIC COMPANY, Ltd., 10/12, Bosworth Road, London, W.10.—Descriptive leaflet giving the latest information on this company's impregnation recording equipment.

AERO RESEARCH, Ltd., Technical Service Department, Duxford, Cambridge.—Bulletin No. 161, entitled "Experiments on Composite Models with Application to Cemented Joints."

THE FLEXIBLES ADVISORY SERVICE OF COMPOFLEX COMPANY, Ltd., 23/25, Northumberland Avenue, London, W.C.2.—Brochure dealing with the manufacture of light and heavy flexible cable transmissions of the push-pull and spring-return types and also speedometer and tachometer cables.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Mon., Oct. 1*st.*—LEEDS BRANCH: Great Northern Hotel, Leeds, "Local and Decorative Lighting," L. A. Fickling, 7.30 p.m.——N.E. LONDON BRANCH: Angel Hotel, Ilford, Film Show, 7.30 p.m.——SHEFFIELD BRANCH: Royal Victoria Station Hotel, Sheffield, "Beam Engines and Other Railway Antiquities," G. F. Jones, 7.30 p.m.

Tues., Oct. 2*nd.*—N. LONDON BRANCH: "Queen's Head," 677, Green Lanes, Harringay, N.4, "Temperature Indication and Control," C. Dupen, 7.45 p.m.——OXFORD, READING AND DISTRICTS BRANCH: Palmer Hall, West Street, Reading, "Radio Frequency Heating," B. Kellett, 7.15 p.m.——S. WALES BRANCH: Angel Hotel, Westgate Street, Cardiff, A.S.E.E. Exhibition Film, 1956, 7.30 p.m.——TYNESIDE BRANCH: Crown Hotel, Newcastle upon Tyne, "Fluorescent Lighting," 7.30 p.m.——W. LONDON BRANCH: Windsor Castle Hotel, 134, King Street, Hammersmith, "Recent Developments in Resistance Welding Applications," C. A. Burton, 7.30 p.m.

Wed., Oct. 3*rd.*—GLASGOW BRANCH: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Switchgear," 8 p.m.——MANCHESTER BRANCH: Engineers' Club, Albert Square, Manchester, Debate on Automation, 7.30 p.m.——PRESTON BRANCH: R.A.F.A. Club, East View, Preston, "Water for the Extinguishment of Oil Fires in Electricity Stations," H. Hoyle, 7.30 p.m.

Thurs., Oct. 4*th.*—S. LONDON BRANCH: Half Moon Hotel, Broad Green, Croydon, "Electrical Safety," S. J. Emerson, 8 p.m.

Fri., Oct. 5*th.*—LIVERPOOL BRANCH: Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, "The Modern Police Force," Chief Inspector Collins, 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Thurs., Oct. 4*th.*—N.W. SECTION: Reynolds Hall, College of Technology, Sackville Street, Manchester, 1, "Education for Electronics," R. H. Garner, 6.30 p.m.

Fri., Oct. 5*th.*—S. MIDLANDS SECTION: North Gloucestershire Technical College, Cheltenham, "Television Lighting Effects," A. E. Robertson, 7 p.m.

Wed., Oct. 10*th.*—W. MIDLANDS SECTION: Technical College, Wulfruna Street, Wolverhampton, "Colour Television," 7.15 p.m.

Thurs., Oct. 11*th.*—SCOTTISH SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "The Digital Computer and its Applications," Dr. Barnett, 7 p.m.

BRITISH INTERPLANETARY SOCIETY

Sat., Oct. 6*th.*—York Hall, Caxton Hall, Caxton Street, London, S.W.1, "The Study of the High Atmosphere in the International Geophysical Year," H. S. W. Massey, 6 p.m.

CHEMICAL SOCIETY

Fri., Oct. 5*th.*—MANCHESTER BRANCH: Chemistry Lecture Theatre, The University, Manchester, "Corrosion Fatigue," U. R. Evans, 6.30 p.m.

ELECTRIC RAILWAY SOCIETY

Thurs., Oct. 4*th.*—Fred Tallant Hall, 153, Drummond Street, London, N.W.1, "Tube Rolling Stock Through the Ages," B. J. Prigmore, 7.15 p.m.

ILLUMINATING ENGINEERING SOCIETY

To-day, Sept. 28*th.*—BATH AND BRISTOL CENTRE: Royal Hotel, Bristol, "Lighting for Enjoyment," T. O. Freeth, 7 p.m.——BIRMINGHAM CENTRE: Regent House, St. Phillip's Place, Colmore Row, Birmingham, Chairman's Address, V. A. Heydon, 6 p.m.

Mon., Oct. 1*st.*—LEEDS CENTRE: Yorkshire Electricity Board Lecture Theatre, Ferensway, Hull, "Home Lighting," Jean L. Stewart, 7 p.m.

Wed., Oct. 3*rd.*—EDINBURGH CENTRE: Y.M.C.A., 14, South St. Andrew Street, Edinburgh, "Light Sources for Colour Matching," E. E. Miles and D. C. Peach, 6.15 p.m.——NEWCASTLE UPON TYNE CENTRE: Grey Hall, Department of Electrical Engineering, King's College, College Road, Newcastle upon Tyne, 1, Chairman's Address, P. S. J. Underwood, 6.15 p.m.——SWANSEA GROUP: S. Wales Electricity Board, The Kingsway, Swansea, Chairman's Address, G. J. Higgs, 6.30 p.m.

Thurs., Oct. 4*th.*—GLASGOW CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Light Sources for Colour Matching," E. E. Miles and D. C. Peach, 6.30 p.m.——NOTTINGHAM CENTRE: Electricity Service Centre, Smithy Row, Nottingham, Chairman's Induction followed by films, 6 p.m.

INCORPORATED PLANT ENGINEERS

To-day, Sept. 28*th.*—S. WALES BRANCH: S. Wales Institute of Engineers, Park Place, Cardiff, Films, "Lubrication and its Importance in Plant Engineering," 7.15 p.m.

Tues., Oct. 2*nd.*—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, "The Treatment and Disposal of Industrial Effluent," J. Lakin, 7 p.m.——EDINBURGH BRANCH: 25, Charlotte Square, Edinburgh, "Incentives for Maintenance," 7 p.m.

Wed., Oct. 3*rd.*—LEICESTER BRANCH: College of Art and Technology, Leicester, "Power Transmission," 6.30 p.m.——SOUTHERN BRANCH: Polygon Hotel, Southampton, Brains Trust on General Matters, 7.30 p.m.

Thurs., Oct. 4*th.*—PETERBOROUGH BRANCH: White Lion Hotel, Church Streeet, Peterborough, "Design of Condensing and Feed Heating Plant," J. Denton, 7.30 p.m.

Mon., Oct. 8*th.*—DUNDEE BRANCH: Mathers Hotel, Dundee, "Silicones," film and lecture, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Mon., Oct. 1*st.*—MERSEYSIDE AND N.W. SECTION: Liverpool Engineering Society, 9, The Temple, 24, Dale Streeet, Liverpool, "Some Teething Troubles in Post-war Reduction Gears," S. Archer; "Some Considerations of Wear in Marine Gearing," W. H. Darlington, 6.30 p.m.

INSTITUTE OF METALS

Tues., Oct. 2*nd.*—OXFORD LOCAL SECTION: Cadena Café, Cornmarket Street, Oxford, "Molybdenum," D. O. Pickman, 7 p.m.

Thurs., Oct. 4*th.*—LONDON LOCAL SECTION: 4, Grosvenor Gardens, London, S.W.1, "The Bonding of Metals and Alloys to Glass and Ceramics," H. Rawson, 6.30 p.m.

INSTITUTE OF PETROLEUM

Wed., Oct. 3*rd.*—26, Portland Place, London, W.1, "Le Havre-Paris Pipeline," J. B. Capdeville, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., Oct. 1*st.*—SCOTTISH CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "The Operation and Development of Disc Brakes," T. J. Phipps, 7.30 p.m.

Tues., Oct. 2*nd.*—EASTERN CENTRE: Canteen, Eastern Counties Omnibus Company, Ltd., Norwich, "The Commer T.S.3 Two-stroke Diesel Engine," E. W. Coy, 7.30 p.m.

Wed., Oct. 3*rd.*—E. MIDLANDS CENTRE: Mechanics' Institute, Nottingham, "Current Trends in Fuel Injection Equipment for Road Transport," J. Skinner, 7.30 p.m.

Thurs., Oct. 4*th.*—LONDON CENTRE: Royal Society of Arts, John Adam Street, London, W.C.2, Annual General Meeting, followed by film, 6.30 p.m.

Mon., Oct. 8*th.*—E. REGIONAL CENTRE: Council Chamber, Houldsworth Hall, 90, Deansgate, Manchester, "Two-Way Radio as an Aid to the Control of Goods and Passenger Vehicles," E. N. Farrar, 7.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Oct. 2*nd.*—AIRPORT MEETING: Great George Street, Westminster, London, S.W.1, "Prestressed Concrete Runways: History, Practice and Theory," A. J. Harris, 5.30 p.m.

Thurs., Oct. 4*th.*—LECTURE ON THE CONSERVATION OF NATURAL RESOURCES: Great George Street, Westminster, London, S.W.1, "Mineral Resources," W. R. Jones, 5.30 p.m.——N.W. ASSOCIATION: Engineers' Club, Albert Square, Manchester, Address by the Chairman, J. A. L. Matheson, 6.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Thurs., Oct. 4*th.*—ORDINARY MEETING: Savoy Place, London, W.C.2, Inaugural Address as President, Sir Gordon Radley, 5.30 p.m.

Tues., Oct. 9*th.*—MEASUREMENT AND CONTROL SECTION: Savoy Place, London, W.C.2, Chairman's Address, "The Measurement of Radioactivity," Denis Taylor, 5.30 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Mon., Oct. 8*th.*—N.E. BRANCH: Northern Architectural Association Hall, 6, Higham Place, Newcastle upon Tyne, "Oil Seals and Packings from the Designers' Point of View," E. T. Jagger, 7.15 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Oct. 2*nd.*—39, Elmbank Crescent, Glasgow, "Industrial Organisation," P. Hanika, 6.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Tues., Oct. 2*nd.*—N.E. COAST BRANCH: Institute of Mining and Mechanical Engineers, Neville Street, Newcastle upon Tyne, 1, Chairman's Address, 6.30 p.m.

Wed., Oct. 3*rd.*—E. MIDLAND BRANCH: College of Arts and Crafts, Waverley Street, Nottingham, "Medium Pressure Hot Water Heating," J. N. Saunders, 6.45 p.m.

Tues., Oct. 9*th.*—BIRMINGHAM AND DISTRICT BRANCH: Exchange and Engineering Centre, Stephenson Place, Birmingham, "Dust Control in Foundries," W. D. Bamford, 6.30 p.m.——S.W. BRANCH: R.W.A. School of Architecture Library, Bristol, "Some Aspects of Intermittent Heating," E. Harrison, 6.30 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

Fri., Oct. 5*th.*—Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "Highway Engineering from a County Angle," I. A. Cram., 5.30 p.m.——N.E. BRANCH: The University, Palace Green, Durham City, "Heavy Haulage by Road Transport," E. G. Milne, 7 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Sept. 28*th.*—N.W. BRANCH: Central College of Further Education, Abbey Road, Barrow-in-Furness, "Water Ring Self-priming Pumps," E. Crewdson, 7.30 p.m.

Mon., Oct. 1*st.*—N.E. BRANCH: Stephenson Building, Claremont Road, Newcastle upon Tyne, 2, Chairman's Address, Aubrey Burstall, 6 p.m.

Tues., Oct. 2*nd.*—S. WALES BRANCH: S. Wales Institute of Engineers, Park Place, Cardiff, Chairman's Address, H. A. V. Bulleid, 6 p.m.

Wed., Oct. 3*rd.*—SOUTHERN BRANCH: College of Technology, Anglesea Road, Portsmouth, "Nuclear Reactors for Power Production," B. L. Goodlet, 6.30 p.m.

Thurs., Oct. 4*th.*—N.W. BRANCH: Engineers' Club, Albert Square, Manchester, "Testing of Boilers and Turbo-Alternators in Power Stations of the Central Electricity Authority," H. S. Hotman, 6.45 p.m.——SCOTTISH BRANCH: Technical College, George Street, Glasgow, "A Criticism of the Technical Education of Recently Qualified Engineers," P. P. Love, 7.30 p.m.——EAST MIDLAND GRADUATES' SECTION: Technical College, Lincoln, Film Evening, 7.15 p.m.

Fri., Oct. 5*th.*—SCOTTISH BRANCH: North British Station Hotel, Edinburgh, "A Criticism of the Technical Education of Recently Qualified Engineers," P. P. Love, 6.30 p.m.

Tues., Oct. 9*th.*—AUTOMOBILE DIVISION, GENERAL MEETING: 1, Birdcage Walk, Westminster, London, S.W.1, Address by the Chairman, 6 p.m.

INSTITUTION OF NAVAL ARCHITECTS

Thurs., Oct. 11*th.*—Weir Lecture Hall, 10, Upper Belgrave Street, London, S.W.1, "Scale Effect Experiments on Victory Ships and Models," Part II, "Analysis of Wake Measurements on a Model Family and the Model Boat, D. C. Endert, Jr.," J. D. van Manen, 4.45 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Mon., Oct. 8*th.*—JUBILEE MEETING: Institution of Electrical Engineers, Savoy Place, London, W.C.2, President's Address, "Fifty Years of Telecommunications," 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Sept. 28*th.*—S. WALES SECTION: S. Wales Institute of Engineers, Park Place, Cardiff, "Induction Heating," R. H. Barfield, 7 p.m.

Wed., Oct. 3*rd.*—NOTTINGHAM SECTION: Victoria Station Hotel, Milton Street, Nottingham, "The 'ings' of Industry," W. H. Telling, 7 p.m.——S. ESSEX SECTION: Mid-Essex Technical College, Chelmsford, "Trade Unions and Industrial Development," R. Harle, 7.30 p.m.——COVENTRY GRADUATE SECTION: Craven Arms, High Street, Coventry, Production Panel, 7.15 p.m.

Thurs., Oct. 4*th.*—READING SECTION: Great Western Hotel, Reading, "The Production Engineer of the Future," E. C. Gordon England, 7.30 p.m.

IRON AND STEEL INSTITUTE

Thurs. and Fri., Oct. 4*th and* 5*th.*—IRON AND STEEL ENGINEERS' GROUP: Thursday: Grand Pavilion, Porthcawl, "The Engineering Aspects of a Modern Basic Bessemer Plant," C. Herrmann, 9.30 a.m. to 12.15 p.m.; Seabank Hotel, Porthcawl, Luncheon, 12.30 p.m. to 1.30 p.m.; Visit to Margam (Blast Furnaces, Coke Ovens and Sinter Plant) and Abbey (Open-Hearth Steel Plant and Wide Strip Mills), Works of the Steel Company of Wales, Ltd., 1.45 p.m. to 4.45 p.m.; Staff Restaurant, Abbey Works, Dinner, 7.30 p.m.; Friday, Grand Pavilion, Porthcawl, "The Planned Changeover of a High-Lift Slabbing to a Universal Mill," C. E. H. Morris and R. N. Dale, 9.30 a.m. to 12.15 p.m.; Esplanade Hotel, Porthcawl, Luncheon, 12.30 p.m. to 1.30 p.m.; Visits to Margam and Abbey Works of the Steel Company of Wales, Ltd., 1.45 p.m. to 4.45 p.m.

LIVERPOOL METALLURGICAL SOCIETY

Thurs., Oct. 11*th.*—The Temple, Dale Street, Liverpool, Presidential Address, W. Rose, 7 p.m.

LONDON ASSOCIATION OF ENGINEERS

Sat., Oct. 6*th.*—Fullers' Restaurant, 206, Regent Street, London, W.1, "Atomic Energy and the Engineer," W. R. Wootton. Film of the New Atomic Power Station at Calder Hall, 6 p.m.

NEWCOMEN SOCIETY

Wed., Oct. 10*th.*—Science Museum, Exhibition Road, South Kensington, London, S.W.7, "The Origin of the Differential Gear and its Connection with Equation Clocks," H. von Bertele, 5.45 p.m.

ROYAL AERONAUTICAL SOCIETY

To-day, Sept. 28*th.*—GRADUATES' AND STUDENTS' SECTION: 4, Hamilton Place, London, W.1, "Novel Methods of Take-off and Landing," T. J. Cummings, 7.30 p.m.

Mon., Oct. 1*st.*—DERBY BRANCH: Rolls-Royce Welfare Hall, Nightingdale Road, Derby, "Sir Henry Royce, Bt.," H. I. F. Evernden, 6.15 p.m.

Tues., Oct. 9*th.*—SECTION LECTURE: 4, Hamilton Place, London, W.1, "The Pressure Jet Helicopter," A. Stepan, 7 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Fri., Oct. 5*th.*—MINING SURVEYORS GENERAL MEETING: 12, Great George Street, Westminster, London, S.W.1, "Sand and Gravel," H. K. Watson; "Ironstone Mining," R. R. Beilby; "Ball Clay Production," C. P. Bates, 5.45 p.m.

SOCIETY OF ENGINEERS

Mon., Oct. 1*st.*—ORDINARY MEETING: Geological Society, Burlington House, Piccadilly, London, W.1, "The Calder Hall Nuclear Power Station," K. J. Frost, 5.30 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Fri., Oct. 5*th.*—FAWLEY SECTION: Copthorne House, Fawley, Hants, "Electrically Operated Process Control Equipment," R. J. Redding, 7 p.m.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE

Fri., Oct. 19*th.*—39, Elmbank Crescent, Glasgow, Symposium on the Application of Low-Alloy Steels for Welded Pressure Vessels, 10 a.m.